Product Engineering

JANUARY 1953

The Mechanics of Industrial Design
Fundamentals of Analogous Systems
Tachometer Generators
Multiple Fluid Circuits and Systems
Why Oil Seals Fail
Cathode Ray Tube Circuits

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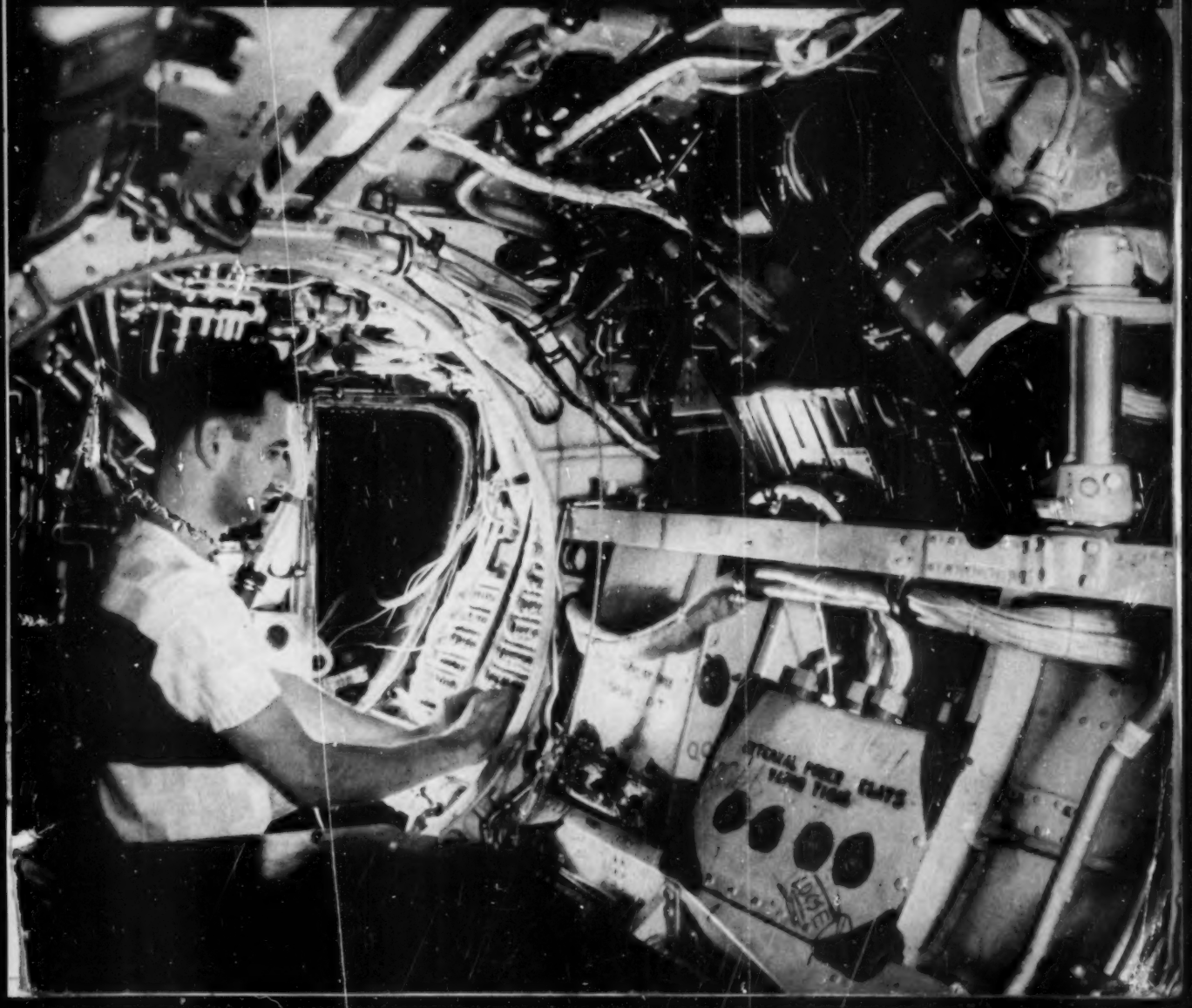
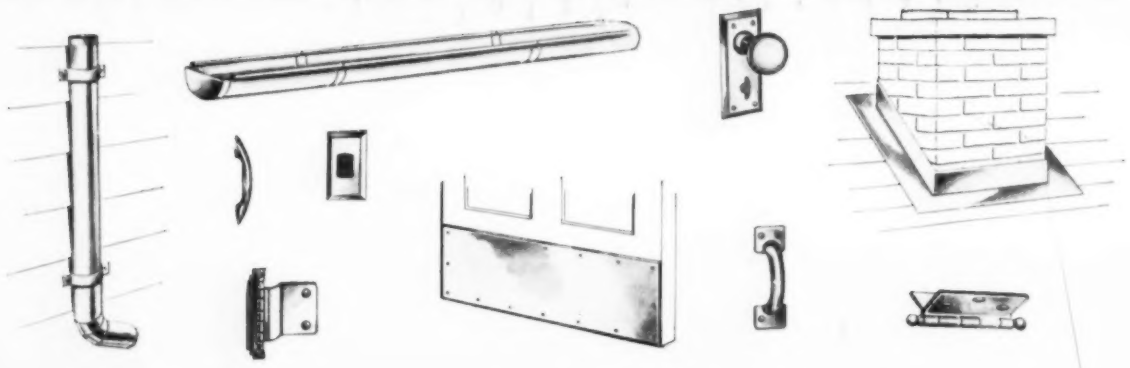
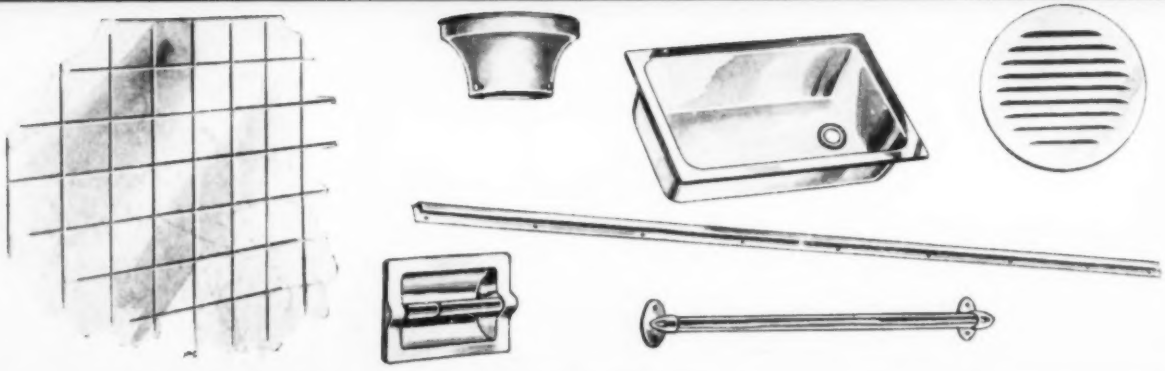


If you are a manufacturer of building products



and are caught in the critical material squeeze



and are looking for a way out . . .

Many manufacturers of building materials find their production seriously threatened by NPA directives limiting or prohibiting production of their products from critical materials. Especially hard hit are manufacturers of building materials normally made of 18-8 stainless, brass, copper, aluminum, or chrome plated.

If your operations fall in any of these categories, then you will want to know more about Sharon '430' Stainless Steel. It is the best available material today for many such applications. Sharon '430' is a straight chromium grade of stainless with a record of successful application.

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Get the facts on this popular stainless today. Contact your nearest Sharon representative or write direct. Engineering data and technical assistance are available without obligation. A new booklet describing how to use Sharon '430' Stainless may be obtained by writing direct to ***Sharon Steel Corporation, Department 71252, Sharon, Pa.***

Those manufacturing gutters, downspouts, flashing, etc., will want a copy of the new information-packed booklet *Sharon '430' for Better Roof Drainage Systems*. Available from district sales offices or by writing direct.

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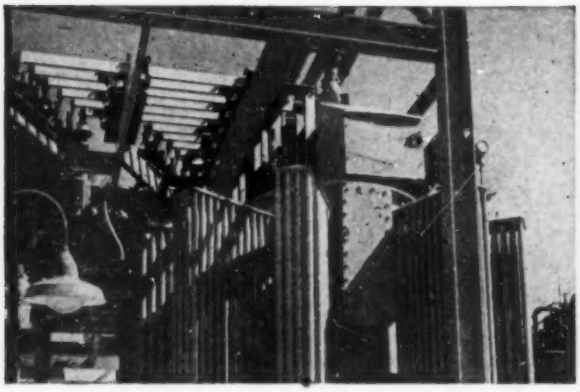

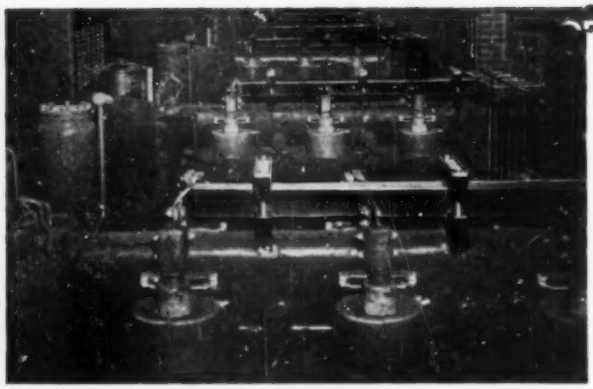

These photographs show a lot of copper bus bar in a new plant of a great chemical company, whose name and location cannot be disclosed. The copper carries heavy currents to electro-chemical equipment for the production of valuable products used in national defense and in industry. Revere furnished 325,000 pounds of bus bar for this service, the bar going into substations, rectifier stations, and cell houses. In addition, at the time of installation the Revere Technical Advisory Service collaborated with the customer in working out some difficult details in the design of switches. If you need electrical conductors, remember that copper has the highest electrical conductivity of all the commercial metals, that Revere makes bus bar, and that the Revere Technical Advisory Service is always ready to work with you on any problem concerning copper and its alloys or aluminum alloys. Call the nearest Revere Sales Office.

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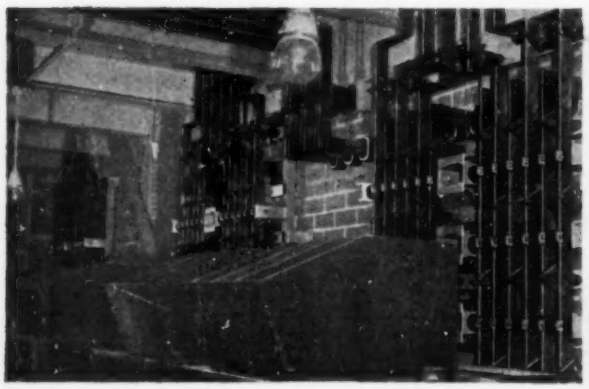

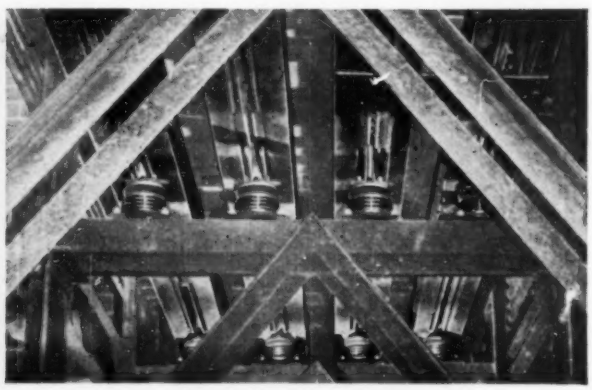

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VOLUME 24

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NUMBER 1

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JANUARY 1953

The Mechanics of Industrial Design 121
Illustrative and model techniques for bringing a product to the final development stage.

Fine Points of Product Development by George Kendall 129
A check list that can result in improved product performance and lower, more competitive costs.

Influence of Strain Gradient on Brittle Coating Sensitivity by A. J. Durelli and S. Okubo 136
Errors caused by neglecting effect of strain gradient in brittle coating stress analysis.

Paper-Thin Metals by Monroe Sherman 138
Special rolling techniques now make available to designers ultra-thin, precision-gage metals.

Product Designs 142
European machine tool tracer attachments; Pulse jet; Air jet operates environmental controls.

How to Prevent Oil Seal Failure by R. O. Isenbarger 154
Essential engineering data needed for proper application plus a check chart for specification.

Tips for Designing Rubber Parts and Assemblies 160
Includes such topics as proper use of metallic inserts and design of molded parts.

Multiple Fluid Circuits by H. L. Stewart 162
Typical applications showing use of pneumatic and hydraulic circuits in a single system.

Performance Characteristics of the Induction Generator Tachometer by Sidney Davis 168
Practical approach to the application of the induction tachometer with sample calculations.

How to Evaluate Assembly Tolerances by R. H. Johnson 179
Shows how statistical methods can be used for nearly all the different tolerance problems.

Cathode-Ray Tube Circuits by Ralph B. Immel 182
Tubes and circuits that can be applied for voltage and current analysis.

Analogous Systems in Engineering Design by R. C. McMaster, R. L. Merrill, B. H. List 184
A discussion of the analogies existing in nature and how they are applied to solve engineering problems.

Common Rubber Materials 203
Properties and typical applications for both natural and synthetic rubber.

Nomograph for Lateral Area of Cones and Pyramids by S. R. Heller 205
How lateral area of right cones and pyramids whose bases are regular polygons can be calculated.

A Graphical Aid for Combined Stress Problems by John P. Hatch 207
Simple graphical construction is helpful in solving stress problems.

Highlights 5
Front Cover 9
Design Perspectives 115
Editorial 119
Technical News 196
New Parts and Materials 208
New Catalogs and Bulletins 240A
Meetings 243
Sans, Souci 244
Engineering Abstracts 246
Our Readers Say 260
New Books 270

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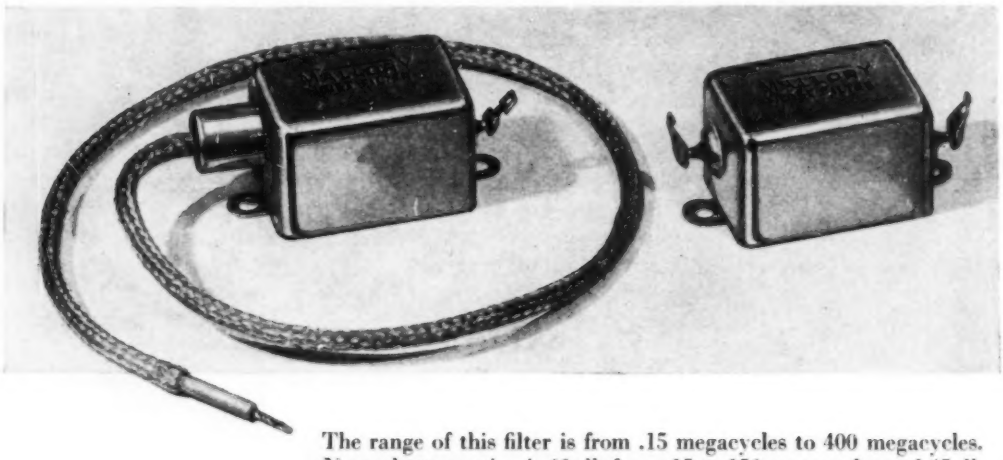
WANTED...

A 5 amp. 50 volt radio noise filter for continuous operation from −55°C. to +125°C. in less than 3 cubic inches

The answer: the Mallory-designed filters pictured meet all the specified requirements.



The range of this filter is from .15 megacycles to 400 megacycles. Normal attenuation is 60 db from .15 to 150 megacycles and 45 db from 150 to 400 megacycles. Its size is only 2½ cu. in. and it weighs only 5 ounces. It is hermetically sealed and *meets all JAN specifications.*

This particular filter may have no application on your present equipment. It demonstrates, however, the result of competent engineering demanded by the increasing complexity of filtering requirements. Electronic equipment has greater sensitivity . . . operates at higher frequencies. As a result, noise suppression must be carefully engineered to hold noise output to the required microvolt level under all operating conditions and over the entire frequency band involved.

Let us analyze your requirements in detail. We are equipped to design the most effective filter for your equipment and manufacture it to any military or civilian specification. Call or write us today.

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Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

SHOCKPROOF QUALITIES of a compounded polyvinyl chloride, designated CPC, has interested the Armed forces in applying it to unusual packaging requirements. Calresin Corp, Arcadia Calif. claims the material meets cold temperature tests, and can be formed or molded to fit any shape. It can be bonded to any surface and is fungus proof and fire proof. Total packaged weight saving is reported to be excellent.

PHOSNIC BRONZE, a high copper alloy containing nickel and phosphorous has been developed by Chase Brass and Copper Co. Waterbury, Conn. It is suited for parts where high strength, high electrical or thermal conductivity, high resistance to fatigue and creep and good workability are required. Severe cold working of any type is possible after age hardening of the material.

HAMER FINISH ENAMEL having ease of application and uniformity of pattern has been announced by the Monroe Sander Corp, Long Island City, N.Y. Developed from a new synthetic resin, enamel is available in a variety of colors. It is claimed that the finish has excellent color retention after baking.

HARDER, THICKER AND DENSER COATINGS are now available for aluminum alloys. Alcoa states that new finishes permit aluminum to be used as gears, sliders, pinions and similar parts on aircraft. Ranging in thickness from 0.001 to 0.005 the coatings are designated Alumilite 225, 226, 725, 726 and Martin Hard Coating. The 225 and 226 finishes are applied to wrought alloys. 725 and 726 to cast alloys. Coating thickness increases part dimension about 50 percent.

HIGH-STRENGTH, STRETCHABLE synthetic rubber has been developed by the Connecticut Hard Rubber Co, New Haven. Excellent durability of the silicone-type rubber at temperature extremes is reported. Material does not lose its bounce when cold and resists heat so well it can be used as oven gaskets. Rubber can be streched more than 600 percent and a one-inch column withstands a pull of 1,900 pounds.

INDICATIONS ARE THAT LOW-PRESSURE silicone glass laminates can be prepared from any glass fabric. Dow-Corning investigations show that excellent laminates from glass fabrics 112, 128 and 181 are possible. Type 181 is preferred because of the ease of handling and molding and the excellent properties obtained. Silicone resin 2104 also appears satisfactory for the production of laminates at pressures of 30 psi or less. At room temperature tensile strengths of 40,000 psi are reported.

METALLIC MATERIALS

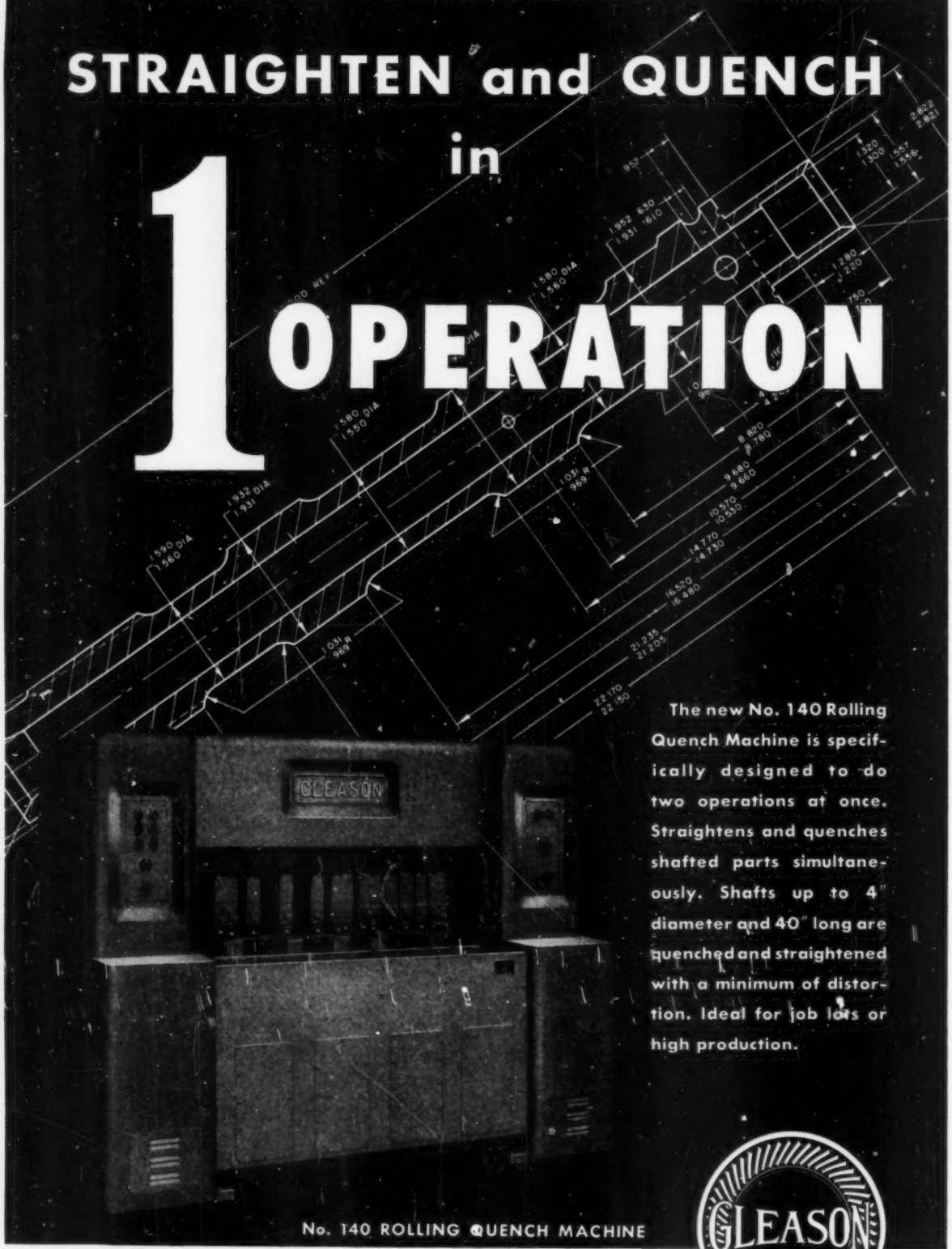
STEEL PLATED with high-purity aluminum has indicated a high resistance to rusting in commercial and sea coast atmosphere. Developed at the Battelle Memorial Institute a bath consisting of ethyl pyridinium, aluminum chloride, toluene and methyl butyl ether is used. Thickness of 0.065 in. and heavier have been obtained.

SHELL MOLDED MIXTURES are being used to cast titanium alloys by the Battelle Memorial Institute. Experiments have shown that mixtures of stabilized zirconia and fused zirconia with four percent of resin makes it possible to melt and cast titanium alloys. Castings are reported to have better surface finishes, greater soundness and reduced surface contamination.

COPPER-CLAD STEELS are being produced for electrical, heat transfer and corrosion applications. Lukens Steel Co., Coatsville, Pa, reports that the plate steel has two types of copper finishes. Oxygen-free high conductivity copper for special electrical applications and phosphorous

(continued on page 7)

STRAIGHTEN and QUENCH in 1 OPERATION



The new No. 140 Rolling Quench Machine is specifically designed to do two operations at once. Straightens and quenches shafted parts simultaneously. Shafts up to 4" diameter and 40" long are quenched and straightened with a minimum of distortion. Ideal for job lots or high production.

No. 140 ROLLING QUENCH MACHINE

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deoxidized copper for improved weldability. Cladding of 10, 15, and 20 percent of total plate thickness are available.

INVESTIGATIONS to determine the temperature at which carbon is fully dissolved in stainless steels have been made by the National Bureau of Standards. Report shows that type 304 ELC (extra low carbon) steel can be effectively annealed at 1,700 F. Normal type 304 stainless must be annealed at 1,900 F. Steels containing a carbon content of 0.007 percent were complete at 1,000 F.

DEVELOPMENT of a ferritic or relatively low alloy steel for high temperature applications is announced by Crucible Steel Co. Pittsburgh Pa. The new steel, designated Crucible 422, is reported satisfactory for high strength bolts and blades in steam and gas turbines. Type 422 contains less than one percent nickel, and only small amounts of vanadium, molybdenum and tungsten. Principle alloy content is 13 percent chromium.

COMPONENTS

A CONTROL TO HOLD THE FREQUENCY of alternators to 0.001 percent on motor generator sets is announced by GE's Special Products Section. To be used with m-g sets up to 10 kw the control is available in 50, 60, and 400 cps models in single or three phase. The unit can be used to prevent undesired hysteresis and eddy current effects in testing or as a standby source of emergency power.

ALL-METAL FLOATING thermometer of the easy reading dial type has been announced by Weston Electrical Inst. Co, Newark, N.J. For use where constant checks on liquids during processing is needed the instrument has a full scale accuracy of ± 1 F. Scale range is 50 to 150 F. and a stem length of five inches.

COMBINING THE FUNCTIONS of a reducing relief valve and filtering arrangement for line service is a new regulator announced by the Industrial Div of Minneapolis-Honeywell Co. Line pressures up to 150 psi can be reduced and maintained at regulated output pressure from 0 to 35 psi without drift or air consumption. Filter and dripwell assure a constant clean supply of air for pneumatically-operated equipment.

120,000 AMP D-C current measuring reactor with a normal accuracy of ± two percent has been announced by General Electric. Main feature is the isolation of the control leads from the current being measured. Leads are energized at 120 V a-c reducing shock hazard at the control panel and lead calibration is not necessary. Device slips over the d-c bus without bus being broken.

DRY-CELL ALKALINE B battery having long-life and small size has been developed by RCA. Rated at 67 1/2 V the cell has an OD of 0.9 in. and is 0.23 in. high. To balance the long life of the B battery a new A cell twice the length of present cells but with four times the life capacity has been developed. The combination can be used as replacements for present A and B batteries.

PROCESSES

SOUND WAVES at 300 to 1,000 kc are used to clean small precision parts. GE unit consist of a vibrating quartz crystal driven by an electronic oscillator. High frequency waves pass through a thin metal diaphragm into a solvent bath. Parts are carried to the bath by a conveyor system. The waves loosen dirt, oil, grease, and other contaminants which are carried away by the bath. Unit is good for cleaning of blind corners.

TRAPPING AND WEIGHING the quantity of carbon dioxide through a test plate is used for measuring the porosity of metal castings. Sam Tour and Co, Inc, New York, states that carbon dioxide of high purity is used at 15 psig in one chamber. Oxygen at atmospheric pressure enters the second chamber. Pressure difference causes carbon dioxide to pass through the test plate proportional to its porosity. Mixture is carried to a carbon dioxide absorbtion tube where weight of gas absorbed gives the leakage rate.

BUTTWELDING of aluminum is being done by the Koldweld Process. Utica Drop Forge and Tool Corp, builder of Koldweld tools, reports that in a manner of seconds an intermolecular flow produces a small compact bond of high tensile strength. Tensile tests show a wire failure will occur before a weld failure. The process work hardens the metal permitting drawing to be done after welding.

(continued on page 9)

Another new development using

B. F. Goodrich Chemical *raw materials*

Radiator cap made by Stant Mfg. Co., Inc., Connersville, Ind., using Hycar rubber seal molded by Acadia Synthetic Products, Chicago, Ill. B. F. Goodrich Chemical Co. supplies the Hycar rubber only.

NEW CAP KEEPS PRESSURE UNDER CONTROL

and Hycar helps!

HYCAR rubber even helps pressurized cooling systems operate efficiently now! For it has all the advantages needed to help the radiator cap pictured provide a perfect seal.

The manufacturer had to have a sealing material that would not stick to the brass radiator filler neck after long contact under spring pressure and heat or moisture. Sticking would prevent the control valve from opening under low pressures.

But that wasn't all. The material also must not swell, shrink, soften or harden under severe service. Hot and cold water, alcohol or chemical-based anti-freeze solutions must not affect it. Nor abrasion produced by fastening or removing the cap.

Hycar nitrile rubber provided the answer to every requirement. For Hycar resists extreme temperatures, oils, acids, many chemicals and abrasion. Its good compression set properties and resistance to cold flow further insure a perfect sealing action.

Hycar rubber compounds are used in many ways—to solve a troublesome problem, or help improve products to bring in more sales. Perhaps they can help you. For technical information and advice, please write Dept. HT-1, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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Hycar American Rubber

GEON polyvinyl materials • HYCAR American rubber • GOOD-RITE chemicals and plasticizers • HARMON organic colors

HEAVY-DUTY PRIMER developed to ease application and assure adhesion of vinyl coatings to metals has been announced by Prufcoat Lab, N.Y. Finishes can be applied after overnight drying of primer. It is an excellent bonding agent for conventional paints and synthetic resins. Primer also inhibits corrosion after only routine surface preparation of the metal.

SCALE REMOVAL of metals by use of periodic reverse current has been announced by Enthrone Inc. New Haven, Conn. Process requires that the part alternate between being positively and negatively charged. Time intervals range from 5 to 30 sec. Removal of black heat treat, quenching, and other scale on steels and alloy steels has been accomplished.

TESTING

LARGE CAPACITY, HEAVY DUTY CENTRIFUGE for operational testing of components and assemblies under high centrifugal and acceleration loads is announced by the Rucker Co, Oakland Calif. Assemblies up to 600 lb can be tested at loadings of 60 g's. Higher loadings are possible for smaller specimens. Components 6 ft. long and 24 in. in section can be accomodated.

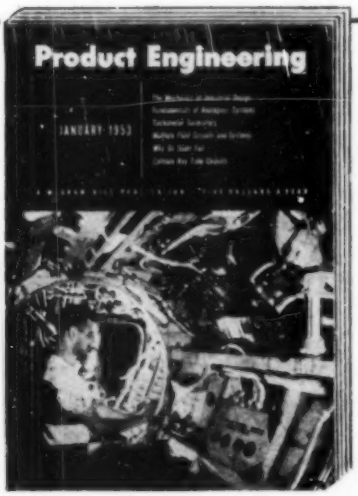
ELEVATED TEMPERATURE TESTS have been conducted on the alloys of zirconium by the U.S. Bureau of Mines metallurgists. The iron-nickel-silver alloys are satisfactory for service up to 1,200 F. Ternary alloys up to 1,400 F and the chromium-cobalt-copper alloys range is 1,000-1,200 F. The remainder of the alloys disintegrated in tests run at 1,200 Fahrenheit.

DOMESTIC GRAPHITE from Alabama and Pennsylvania are as good as imported graphite from Madagascar for nonferrous metal crucibles. National Bureau of Standards tests also prove that carbon-bonded crucibles have longer service life than clay-bonded crucible. Number of heats before failure of carbon-bonded types were 81.3, 107.7 and 76.0 for Alabama, Pennsylvania and Madagascar graphites respectively. Clay-bonded crucible figures were 40.6, 36.7 and 37.6.

MAGNESIUM ANODES have successfully inhibited hull corrosion according to Bethlehem Steel Company. A rail of magnesium anodes was fasted to a ship hull. Inspection of the hull showed virtually no rust or corrosion pits after one year of ocean-going service.

RAPID TRANSIENT PRESSURE SURGES and high frequency pulsations encountered in processing equipment and hydraulic control systems can be measured with a pressure transducer. Consolidated Engineering Corp, Pasadena, Calif states that the output may be recorded on an oscillograph or used to indicate pressure changes on meters or oscilloscopes. These may be visually monitored.

ENVIRONMENTAL TESTING OF AIRCRAFT components will be simplified by use of two new testers. Built by Bowser Inc, Terryville, Conn., one unit will simulate altitudes up to 80,000 ft or temperatures from -85 to 167 F. Second unit temperature range will be from 80F to 160F combined with wind velocities from 100 to 2,300 fpm to simulate desert atmospheres. Premeasured quantities of dust can be added to subject the test piece to abrasion and clogging.

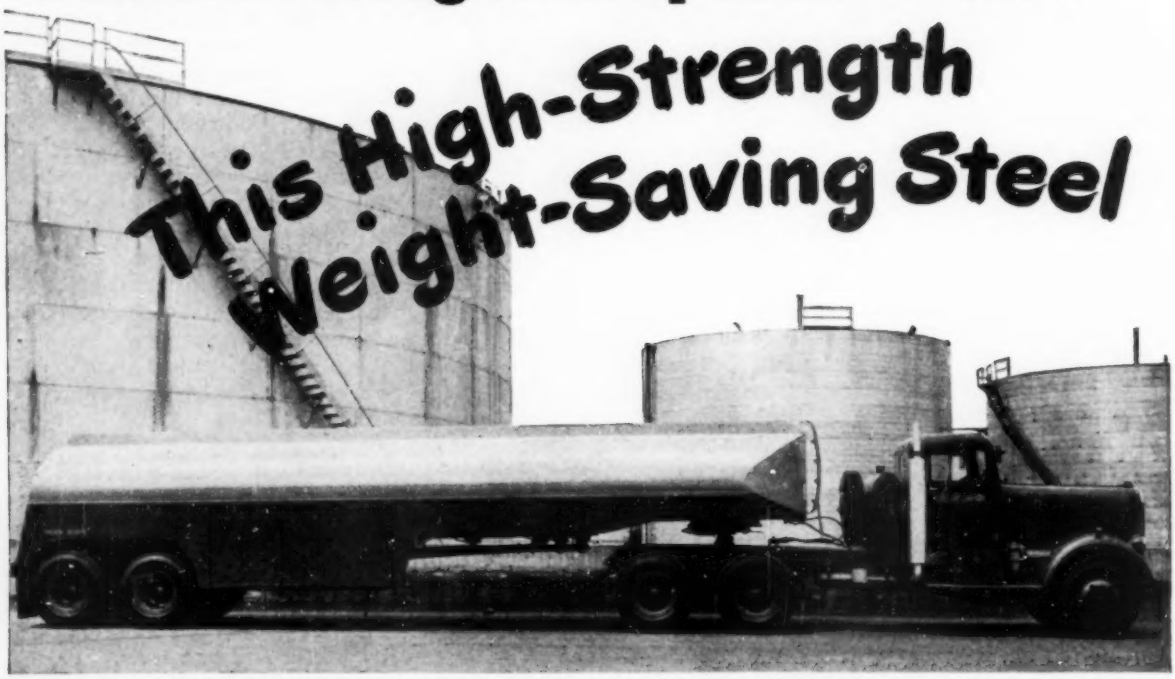


THIS MONTH'S COVER

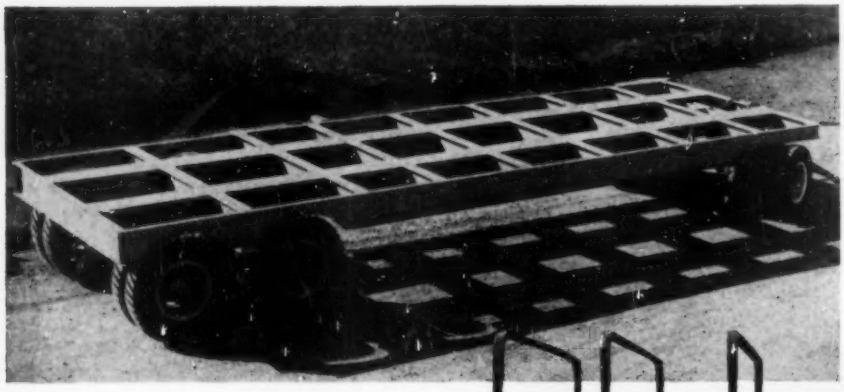
This month's cover pictures wiring connections on the main terminal board of an F-84G Republic Thunderjet fighter-bomber. Importance of electricity in this battle-tested aircraft is attested by several miles of wiring contained within the mere 36-foot wing span and 38-foot length. Electric power actuates trim tabs; permits selection of the type of armament to be fired and the frequency of firing; controls bomb release, which must be accurate to fractions of seconds if a bomb dropping from the 600 mph plus plane is to hit its target; furnishes power for the all-important electronic gunsight; controls vital instruments; powers fuel pumps permitting the pilot to select tanks to be used to assure a finely-balanced plane, and performs other functions.

The F-84G Thunderjet, only production fighter equipped for in-flight refueling, shortly will be succeeded by the new swept-wing F-84F.

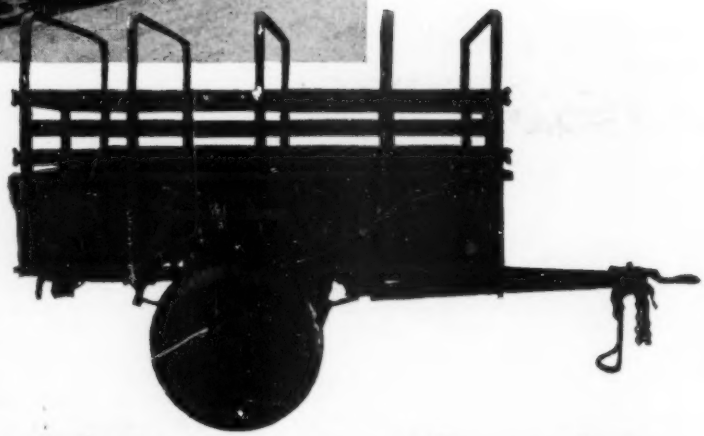
Trailer Designs Improved with This High-Strength Weight-Saving Steel



Almost one ton of deadweight is eliminated from this 7000-gal oil tanker by the use of light-gage Mayari R steel. A considerable increase in payload is made without excceding the legal axle-load limit. Clough Equipment Service of Seattle, Wash., are the builders.



A special 60-ton capacity, heavy-duty trailer designed to carry large machinery in a scrap-recovery plant. All of the principal members are of low-alloy, high-strength Mayari R. The use of this steel increases the strength of the vehicle without adding to its deadweight. The builders are Rogers Brothers Corporation, of Albion, Pa.



This lightweight two-wheel trailer is designed to be airborne. The use of Mayari R keeps the deadweight to the minimum, yet provides adequate strength for rugged cross-country hauling. The trailer was built by Linn Coach and Truck Division of Great American Industries, Inc., Oneonta, N.Y.

BETHLEHEM STEEL COMPANY

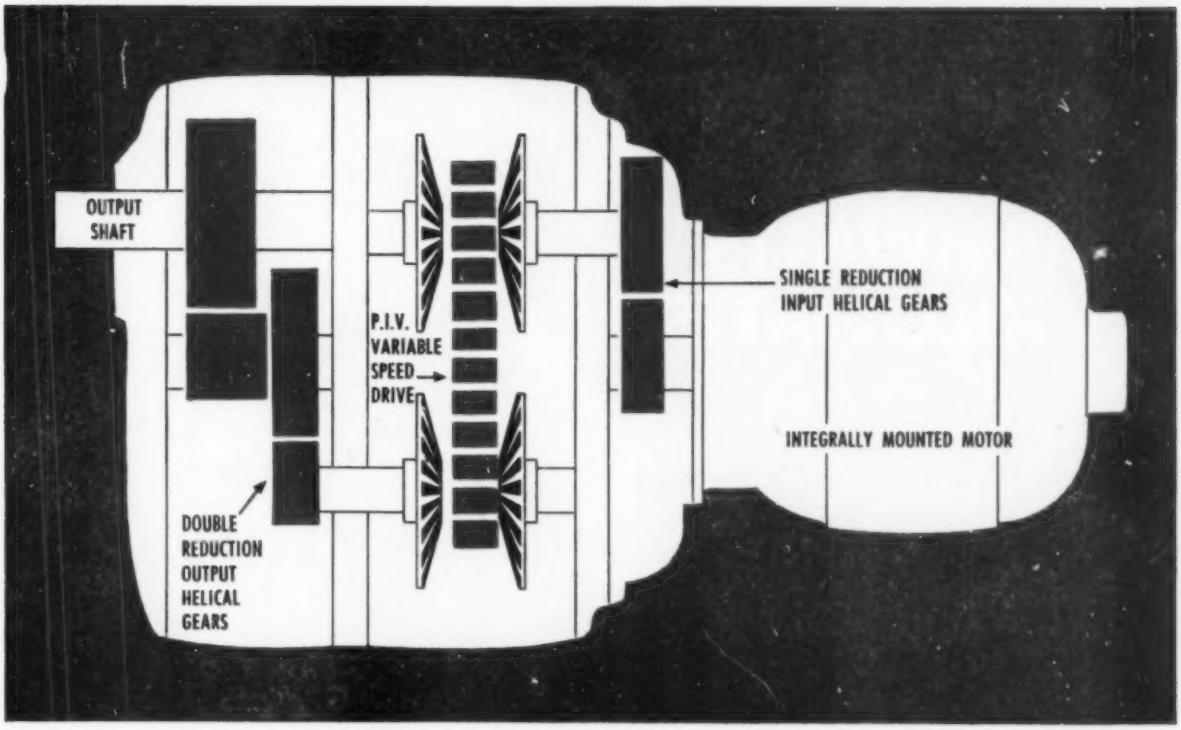
BETHLEHEM, PA.

BETHLEHEM STEEL

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

Mayari R *makes it lighter... stronger... longer lasting*

Here's a complete package...



-- motorized variable speed drive PLUS speed reducer

Whether your variable speed problem is simple or complex, Link-Belt's P.I.V. can increase the flexibility and efficiency of your machines. For this variable speed drive is not dependent on friction—you get exact speed selection in *positive,* infinitely variable settings.

Shown here is the Model HMDG. Both input and output helical gears and the variable speed drive are lubricated from a common reservoir. This is just one of dozens of P.I.V. drives Link-Belt power transmission engineers can choose from to match your exact requirements. Available in 8 types—vertical or horizontal—with or without extra reduction gears—with or without motors.

LINK-BELT
P.I.V. VARIABLE SPEED DRIVE

LINK-BELT COMPANY: Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa), Sydney (Australia). Offices in Principal Cities. 12.841

ALL INDUSTRY USES P.I.V.*
*Positive, infinitely variable

You can get instant speed changes and maintain them accurately while operating under full load.

An infinite number of positive, stepless speed adjustments may be made with manual, electric, pneumatic or hydraulic controls.

Easy-view speed indicator facilitates speed selection and adjustments to meet all requirements.

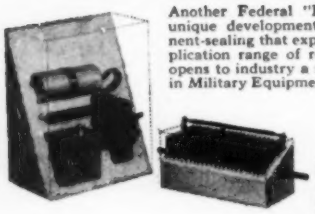
All-metal, totally enclosed — unaffected by atmospheric conditions. All vital operating parts splash-lubricated from a common housing reservoir.

Self-tooth-forming chain grips toothed wheels positively without slippage — gives the speed you need at any setting.

From
SUBMINIATURE to HEAVY DUTY
From
MILLIWATTS to KILOWATTS

Whatever the DC requirement there's a *Federal* SELENIUM RECTIFIER to do the job!

Now Federal Offers ENCAPSULATION OF SELENIUM RECTIFIER STACKS —plus other components



Another Federal "First" . . . a unique development in component-sealing that expands the application range of rectifiers and opens to industry a new concept in Military Equipment Design.

Applications range from tiny rectifiers to sub-assemblies and complete power supplies.

FOURTEEN years ago Federal introduced the selenium rectifier to America's electronic engineers and product designers.

Today, *tens of millions* of these versatile AC-to-DC power conversion units are at work in almost unlimited fields of application . . . from subminiatures with milliwatts of output to heavy duty stacks for the biggest DC-operated equipments.

Here's *proof* of the *high quality* built into Federal's compact, economical, long-life, fully inert selenium rectifiers . . . here's *proof* of their *efficiency* and *dependability* in consumer, industrial and military power conversion jobs!

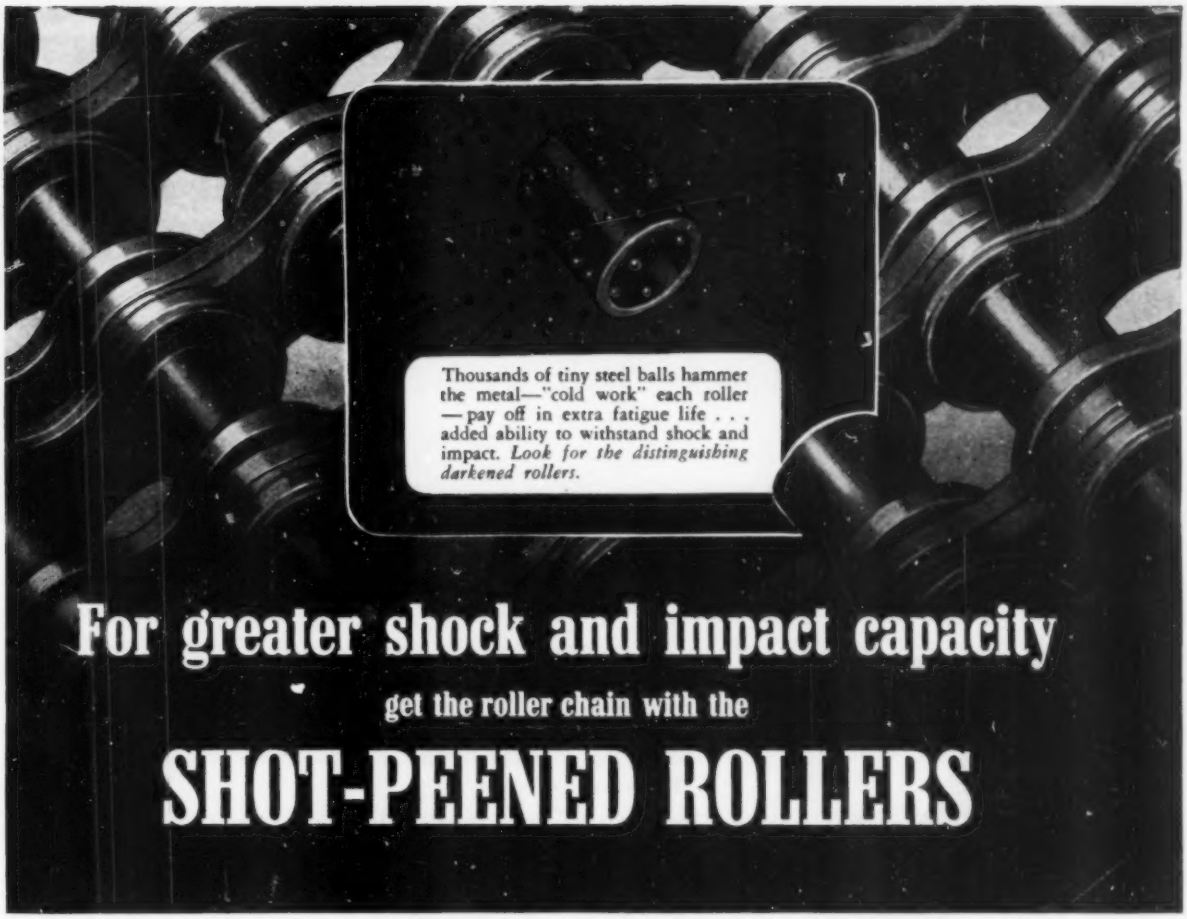
Write Federal today for information on *your* rectifier requirements . . . whatever the size, type or rating. Give your design the benefit of the research, engineering and manufacturing skill that *pioneered* the selenium rectifier . . . and now *keeps* "Federal" the standard of industry! Address Dept. F-442.

America's oldest and largest manufacturer of selenium rectifiers

Federal Telephone and Radio Corporation

SELENIUM-INTELIN DIVISION 100 KINGSLAND ROAD, CLIFTON, NEW JERSEY

In Canada: Federal Electric Manufacturing Company, Ltd., Montreal, P. Q.
Export Distributors: International Standard Electric Corp., 67 Broad St., N. Y.


Thousands of tiny steel balls hammer the metal—"cold work" each roller—pay off in extra fatigue life . . . added ability to withstand shock and impact. *Look for the distinguishing darkened rollers.*

For greater shock and impact capacity

get the roller chain with the

SHOT-PEENED ROLLERS

. . . one of the extra-wear features you get with every LINK-BELT Roller Chain

JUST as shot-peened rollers give you extra fatigue life—so do Link-Belt's exclusive lock-type bushings multiply roller chain's capacity to withstand shock loading. And there are many other engineering extras that make Link-Belt Precision Steel Roller Chain your best buy for drive and conveying service.

You can choose from the complete range of Link-Belt Precision Steel Roller Chain. Ask your nearest Link-Belt office for full particulars on single or multiple widths, in ⅜″ through 3″ single pitch, or double pitch, 1″ through 3″.

Lock-type Bushings increase ability to withstand severe operating conditions

No partial bearing here — bushing fits securely

A special manufacturing process securely locks the inside sidebars on the bushing, preventing lateral movement of the sidebars and eliminating a common cause of stiff chains. This Link-Belt development is applied on roller chains through 1″ pitch and double pitch roller chains through 2″ pitch. 12,098

LINK-BELT

PRECISION STEEL ROLLER CHAIN

LINK-BELT COMPANY: Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa), Sydney (Australia). Offices, factory branch stores and distributors in principal cities.

Whether the job is BIG or small uniform *Carpenter* tubing speeds fabrication

The giant on the left and the pygmy on the right are both heaters—both are made from Carpenter Stainless Tubing—and the manufacturers selected Carpenter for essentially the same reasons.

Whether the job calls for a large immersion heater for heating chemicals in batch tanks or a small heating unit for a soldering iron, these fabricators know that the consistent uniformity in analysis, tolerance and finish of Carpenter tubing makes their production move smoothly and gives them the finest possible finished product.

When you want to discuss your design or fabricating problems, call your nearby Carpenter Stainless Tubing Distributor. He will be glad to put his experience to work for you. The Carpenter Steel Company, Alloy Tube Division, Union, N. J.

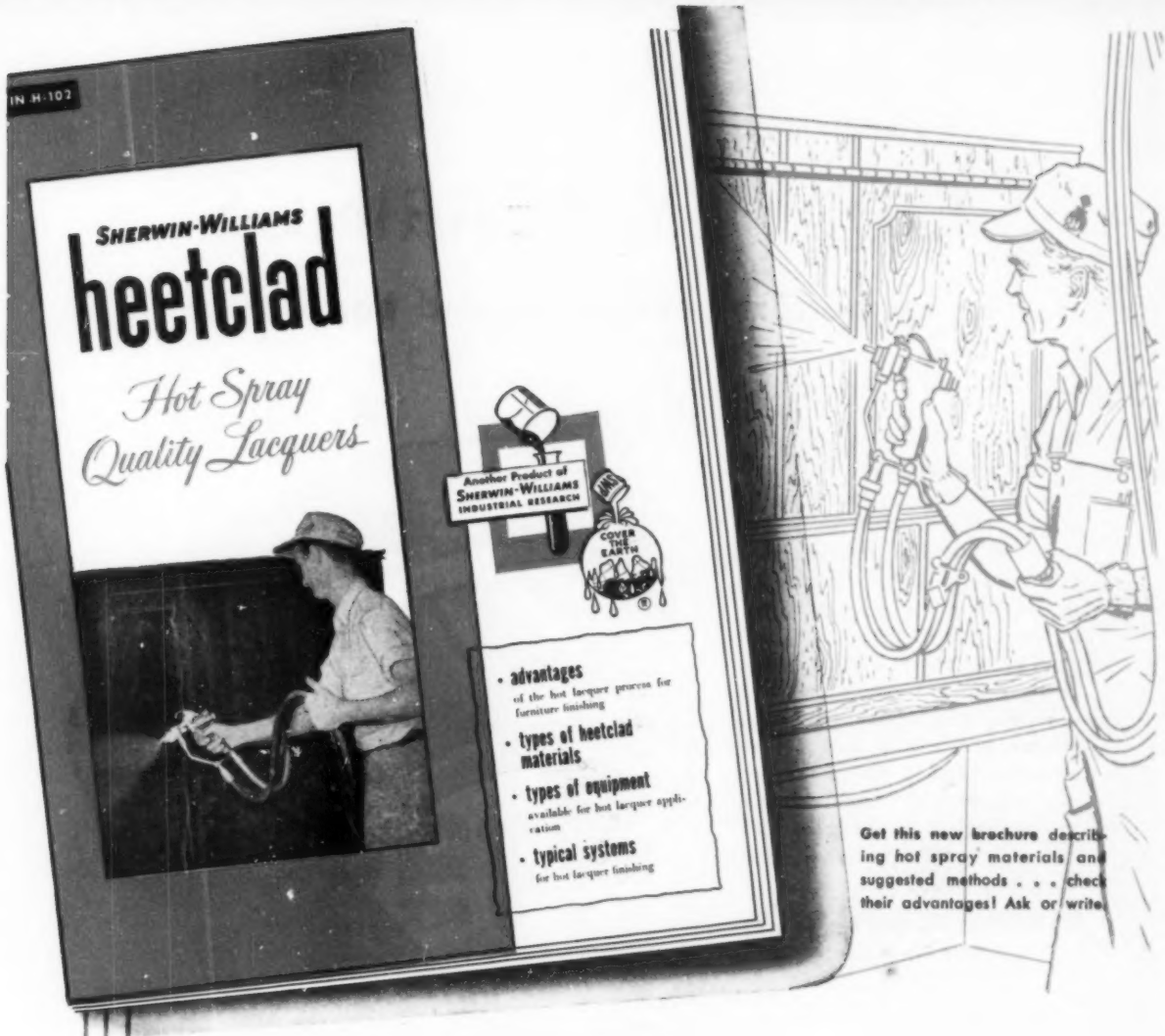
Export Dept.: The Carpenter Steel Co., Port Washington, N.Y. "CARSTEELCO"

Carpenter

STAINLESS TUBING & PIPE

Analysis — Tolerance — Finish

- guaranteed on every shipment



COLD FACTS on HOT LACQUERS

- How to apply them
- Where to use them
- How they save on finishing costs

Does hot spray application offer worth-while advantages in your product finishing operations? What are the types of hot spray materials available and what are their properties? Why are special formulations desirable?

You'll find helpful information on these and other questions on this important development in this new Sherwin-Williams brochure. In addition to discussing where and how the hot spray process can be used to advantage, it includes specifications on two lines of Sherwin-Williams lacquers specifically adapted for hot application, together with representative hot lacquer finishing schedules.

If your operations include the finishing of furniture or wood products, you'll want this data on Heetclad Lacquers. Ask your Sherwin-Williams industrial representative for a copy or write The Sherwin-Williams Co., General Industrial Division, 101 Prospect Ave., Cleveland 1, Ohio.

SHERWIN-WILLIAMS

INDUSTRIAL FINISHES

QUALITY BEARINGS

step up performance of rugged earth movers!

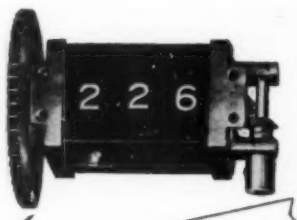
It's difficult to find a type of equipment that places more wear and tear on bearings than today's giant earth movers! Bower Spher-O-Honed bearings, because they are built to such high quality standards, are used extensively by leading manufacturers of earth moving equipment. Precise, honed races, generous oil groove and spherical roll heads and flange surface are only a few of the advanced Bower features which add to bearing life and minimize breakdowns. Standardize on Bower Spher-O-Honed bearings for your product!

THE BOWER ROLLER BEARING COMPANY
Detroit 14, Michigan

BOWER

SPHER-O-HONED

ROLLER BEARINGS



Small Component...
or Complete Unit...
You* can count on
getting whatever
You* need—

Added Evidence
that—

Everyone Can Count on VEEDER-ROOT

This REEL CONTROL BOX, complete with its *built-in* counting mechanism, indicates the number of feet of antenna reeled in and out of certain types of military aircraft. Manufactured completely by Veeder-Root, including outside bakelite cover and box, this unit shows another imaginative application of the universal language of direct-reading *Count*rol.

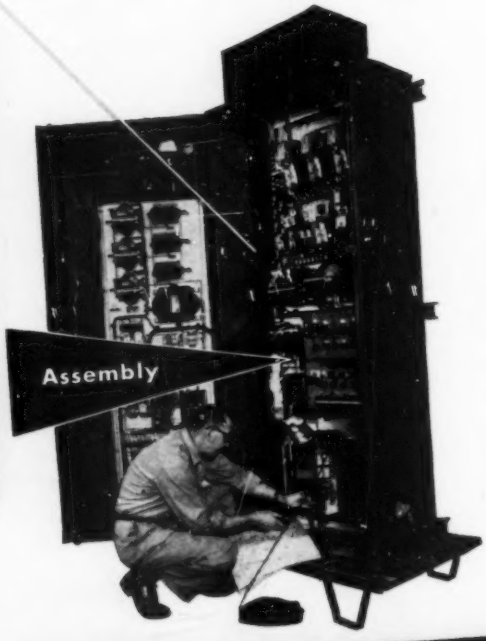
Now if you, *in any of your defense work,** have a counting problem, then you can count on Veeder-Root to help you in every possible way.

VEEDER-ROOT INCORPORATED
"The Name That Counts"
HARTFORD 2, CONN. • GREENVILLE, S.C.
Montreal 2, Canada • Dundee, Scotland
Offices and agents in principal cities

"Counts Everything on Earth"

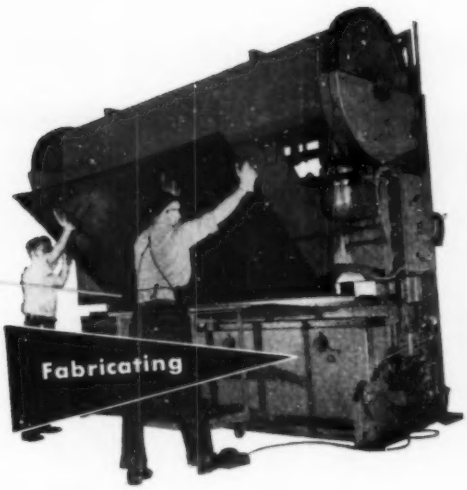
offers you BETTER Custom-built Motor Control

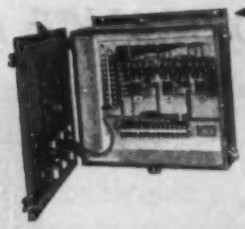
• Square D's latest contribution to design leadership—completely integrated "job shop" operations for design and manufacture of custom-built motor control. These new facilities operate independently of Square D's general manufacturing plants. They utilize the full-time, specialized skills of engineers and craftsmen. They add vital support to Square D Field Engineers in meeting special control needs.



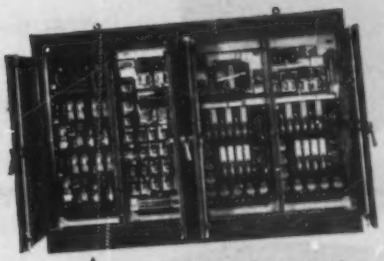
SQUARE D COMPANY

..SIMPLE OR COMPLEX—LARGE OR SMALL





Square D builds special controllers ranging from those requiring only a few simple components *(at left)* to those employing hundreds of inter-connected devices *(below)* for controlling complex machine tools and processes.



A large AC-DC controller for machinery requiring both adjustable and constant speed motors.

Custom-built controllers can be constructed in accordance with NMTBA, IIC, and individual customer specifications. The one at left meets IIC standards.

Engineered, Factory-Assembled and Tested by

SQUARE D COMPANY

This label reflects quality and performance standards which are achieved by a complete integration of engineering, assembling and testing—all under factory control.

SQUARE D COMPANY, Dept. 75
4041 N. Richards Street, Milwaukee 12, Wis.

Please send me a copy of your new booklet which gives the complete story of Square D's new JOB SHOP OPERATION.

Name _____

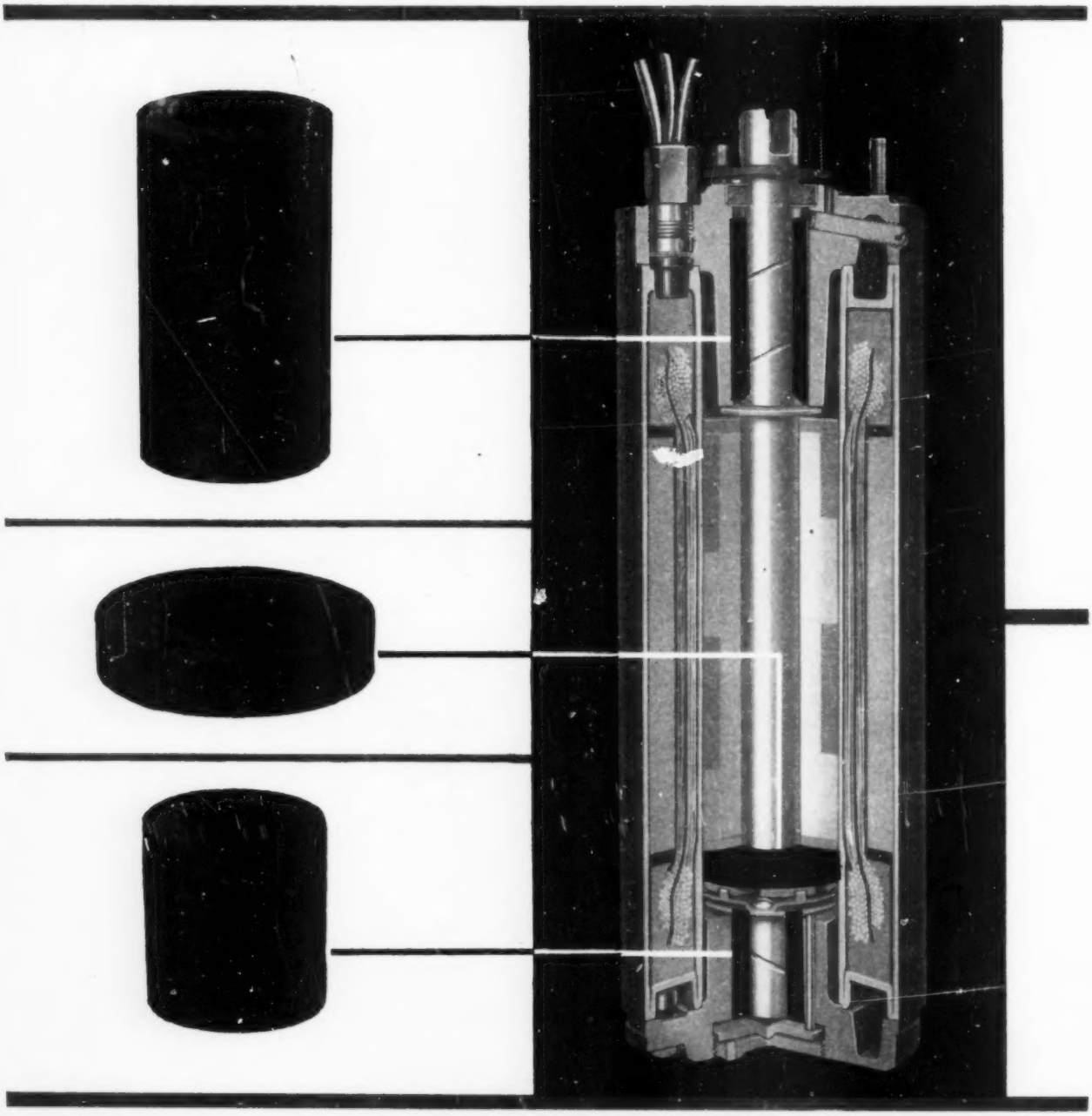
Address _____

City _____ Zone _____ State _____

GRAPHITAR® shaft and

(CARBON-GRAPHITE)

PEAK PERFORMANCE AND LONG LIFE IN THE



THE UNITED STATES

thrust bearings HELP INSURE

FRANKLIN SUBMERSIBLE DEEPWELL PUMP MOTOR

The Franklin Submersible Deepwell Pump Motor is made by the Franklin Electric Co., Inc., of Bluffton, Indiana. To keep it operating at peak efficiency for years of difficult underwater service, the motor is equipped with two **GRAPHITAR SHAFT BEARINGS** and a GRAPHITAR thrust bearing. Even at speeds up to 3450 rpm's and thrust loads of 300 and 900 lbs., these GRAPHITAR parts need no lubrication other than the water in which they operate. They will not rust or corrode and they practically never wear out. **GRAPHITAR SEALS, BEARINGS** and other specialty parts are available in many different grades to meet the requirements of specific applications. They can help reduce your costs and improve the performance of your products. For complete information, write us today.

GRAPHITAR is a versatile engineering material produced from carbon-graphite powders, compacted under terrific pressures and fused at temperatures exceeding 3000° F.

- GRAPHITAR can be formed in relatively intricate shapes and ground to tolerances as close as .0005".
- GRAPHITAR is lighter than magnesium, yet mechanically strong and durable, making it ideal for use where weight is a factor.
- GRAPHITAR is highly resistant to wear.
- GRAPHITAR is practically unaffected by high speeds, high pressures or temperature extremes.
- GRAPHITAR is self-lubricating and needs no oil.
- GRAPHITAR is chemically inert and will not corrode even when exposed to concentrated acids.
- GRAPHITAR is always available in virtually unlimited quantities.

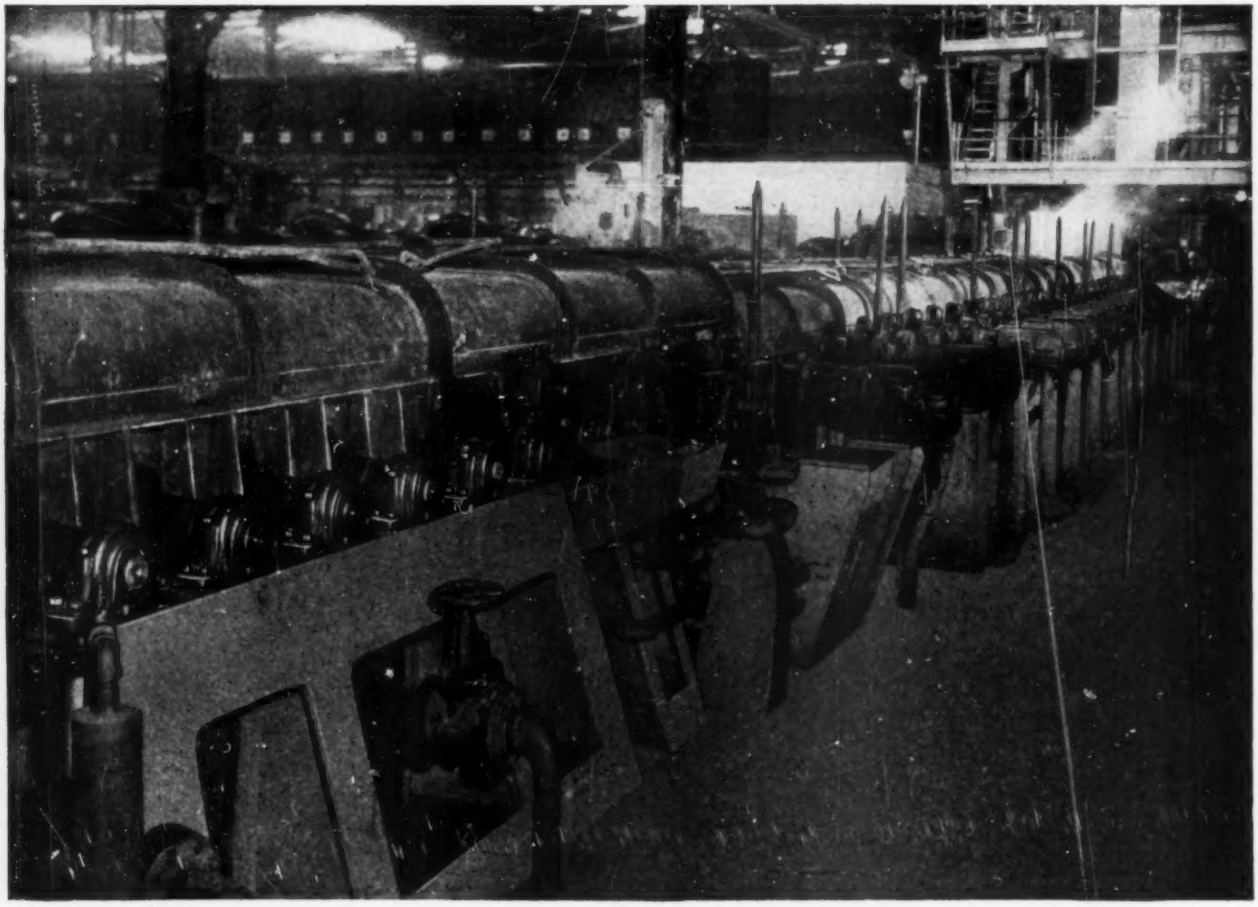
176

GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW, MICHIGAN

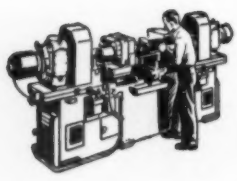
LINK-BELT ball and

...keep company with

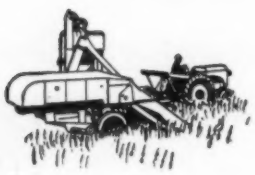


Continuous steel strip is electrolytically tinplated at the rate of 1500 feet per minute on this modern new production line—almost twice the speed of previous comparable lines. Shown above are pillow blocks supporting the shafts on each end of the 26 contact rolls.

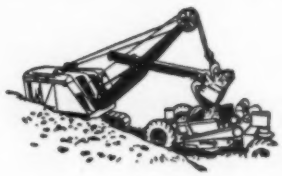
LINK-BELT ball and roller bearings



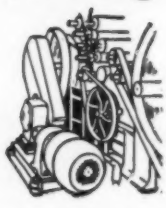
Metal Working Machinery



Farm Machinery



Construction Equipment



Textile Machines

roller bearings

America's hardest-working machines

The efficiency and life of any machine are dependent on the quality and accuracy of its bearings. That's why so many equipment designers specify Link-Belt on their heaviest-duty machines.

Link-Belt precision Ball and Roller Bearings have proved—on tens of thousands of applications—that they are the long-life answer for tough service. Integrally self-aligned, they have full load capacity for both thrust and radial loads.

There are Link-Belt ball or roller bearings to meet every industrial need, and a Link-Belt bearing specialist near you will help apply them to your particular requirements. You can also get all the facts from Data Book 2550.

CUTAWAY OF SERIES 6800-6900
TWO-PIECE ROLLER BEARING PILLOW BLOCK
Self-aligning—inner raceway is truly spherical, free to move in any direction without altering contact area with rollers. Full load capacity always assured even with shaft deflection or misalignment.
Jack screw holes are provided for easy removal of housing cap.
Tapered adapter sleeve provides positive concentric mounting on commercial shafting.
Large reservoir prolongs lubrication intervals.
Easily installed by removing housing cap, slipping adapter assembly onto shaft and locking in position.
Sturdy, two-piece cast housing facilitates installation, inspection and disassembly.
Seals effectively keep lubricant in, dirt out.
"Housing sealing" feature fully protects and lubricates all moving surfaces.
Slotted bolt holes facilitate mounting on supporting structure.
One of many types in the Link-Belt line of Pillow Blocks, Flanged, Flanged Cartridge, Cartridge, Hanger, Take-Up Blocks and Unmounted Bearings.

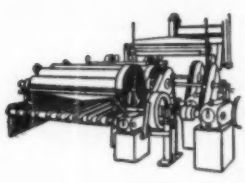
LINK-BELT

BALL and ROLLER BEARINGS

12,640A

LINK-BELT COMPANY: Plants: Chicago, Indianapolis, Philadelphia, Colmar, Pa., Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle, Toronto, Springs (South Africa), Sydney (Australia). Sales Offices, Factory Branch Stores and Distributors in Principal Cities.

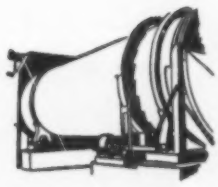
smooth the path of power for all industry



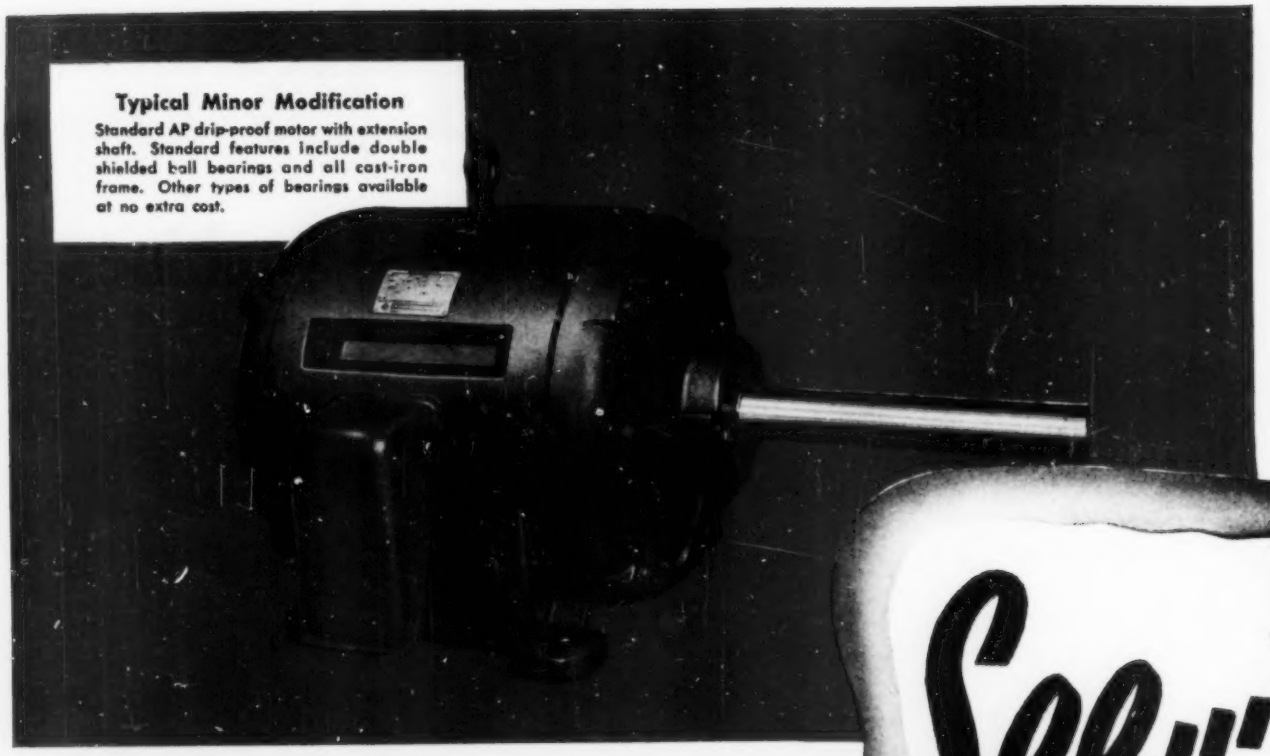
Pulp & Paper Machinery

Materials Handling Equipment

Oil Field Equipment



Processing Equipment



Typical Minor Modification

Standard AP drip-proof motor with extension shaft. Standard features include double shielded ball bearings and all cast-iron frame. Other types of bearings available at no extra cost.

See...

Typical Special Design

Special 36-volt dc motor built for large lift truck manufacturer. Weight and size were kept to a minimum while torque and power consumption curves were tailored to fit the special requirements of battery operation.

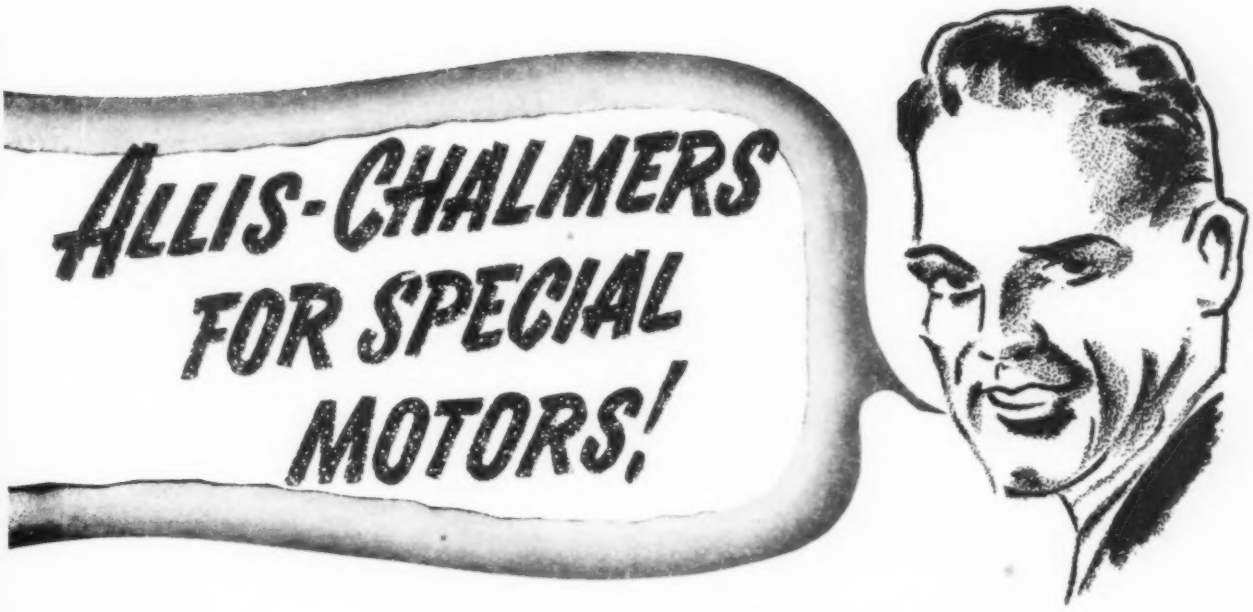
Coordinated Drive Components From Power Line To Machine

MOTOR CONTROL

MOTOR

Texrope **V-BELT DRIVE**

Minor Modification or Major Design Problem?



BRING YOUR SPECIAL MOTOR PROBLEMS TO ALLIS-CHALMERS. A-C design engineers are familiar not only with motor design but also with control and drive characteristics and with the load characteristics of a great many types of driven machines. They know the problems of the design engineer intimately because Allis-Chalmers designs and manufactures control, drives and many types of machines in its own plants.

Modern Testing Facilities — You can be sure that an Allis-Chalmers special motor will deliver the performance designed into it because every special design is tested in one of the most modern motor laboratories in the industry. Every detail of construction and performance is checked and rechecked before the motor is put into production, and additional tests are run on production units.

Nation-wide Service — Almost 100 Allis-Chalmers Certified Service Shops, located in every major industrial area in the country, are equipped to give prompt, factory approved service on any Allis-Chalmers motor you put on your equipment. In cases where special motors are used, the Certified Service Shop has access to factory data and uses only factory approved parts and procedures. You don't need to worry about service when you use an Allis-Chalmers special motor.

When your machines require special motors call in the Allis-Chalmers representative early in the planning stage. He may be able to make valuable suggestions that will contribute materially to lower product cost and better product performance. Call your nearby Allis-Chalmers District Office or write Allis-Chalmers, Milwaukee 1, Wisconsin. A-3641

Texrope is an Allis-Chalmers trademark.

ALLIS-CHALMERS A-C ALLIS CHALMERS

4 IDEAS TO HELP YOU SAVE
on Bellows Assemblies

IDEA NO. 1 You can get expert help from us for any application where bellows assemblies are used . . . where there's a design problem involving control of temperature or pressure.

IDEA NO. 2 You can get from us bellows assemblies designed to open and close valves, dampers, etc., absorb expansion, provide packless construction and to do many more jobs.

IDEA NO. 3 You can get from us bellows assemblies made to your specific requirements—to give you better performing products and equipment.

IDEA NO. 4 You make cost-savings, too, when you turn over to us your current or projected bellows assemblies requirements. Skilled personnel assure you quality workmanship. Ample facilities can produce for you in any volume—wide range of metals and sizes. You get *all* the advantages of our half-century of experience in this specialized field.

MORE IDEAS! You'll get them when you send for Catalog AP-1200. Write today.

FULTON SYLPHON DIVISION Knoxville 4, Tenn.

Robertshaw-Fulton CONTROLS COMPANY
EVERYTHING'S UNDER CONTROL
TEMPERATURE CONTROLS • BELLOWS ASSEMBLIES • BELLOWS DEVICES

BRIDGEPORT THERMOSTAT DIVISION Bridgeport 1, Conn.

Providing the sinews to bite through steel

Transmitting power to shear through steel pipe requires a drive of rugged strength. The Foote Bros. Hygrade Worm Gear Drive selected for this service provides the maximum in quality and high efficiency due to advanced engineering — improved design — new techniques in manufacture and better control of material.

Whatever your requirements in enclosed gear drives, you will find one just suited to your needs in the complete Foote Bros. line. A size and type of drive for every need.

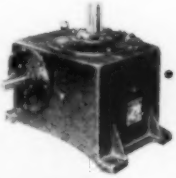
Crop End Saw built by The Enterprise Company, Columbus, Ohio, for National Tube Division of United States Steel Company.

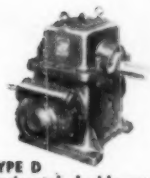
HYGRADE A COMPLETE FAMILY OF ENCLOSED DRIVES

TYPE S
Horizontal right angle worm gear drive. Ratios up to 71 to 1. Cap. up to 266 h.p.

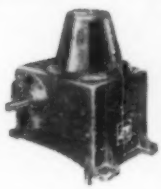
TYPE X
Right angle helical — worm gear drive. Ratios up to 196 to 1. Cap. up to 71 h.p.

TYPE V
Vertical right angle drive, output shaft up, down, or both. Ratios up to 4108 to 1. Cap. up to 216 h.p.





TYPE D
Horizontal double worm gear drive. Ratios up to 4108 to 1. Output torque to 253,000 in. pounds.



TYPE VW
Hytop vertical right angle drive for long, unsupported output shaft extensions. Same ratio and capacity range as TYPE V.

FOOTE BROS.

Better Power Transmission Through Better Gears

FOOTE BROS. GEAR AND MACHINE CORPORATION
Dept. W, 4545 South Western Boulevard, Chicago 9, Illinois

Please send me Bulletin HGB on FOOTE BROS. Hygrade Worm Gear Drives.

Name.....

Company.....

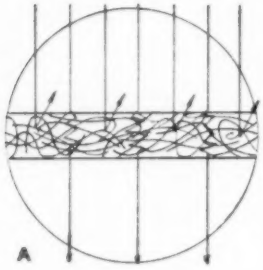
Position.....

Address.....

City..... Zone..... State.....

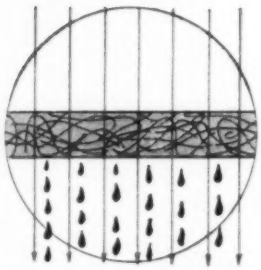
Most tracing paper is made ... and why ALBANENE* is Different

TOUGH, LONG-FIBER PAPER
NOT TRANSPARENTIZED



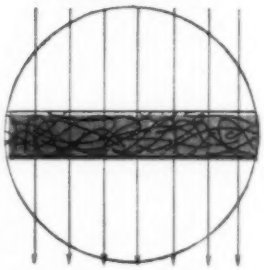
Diagrammatic enlargement of cross section of paper with high strength but low transparency. Fibers are surrounded by air, which has different index of refraction. Many light rays are bent back and do not get through.

SAME PAPER
TRANSPARENTIZED WITH FLUID MATERIAL



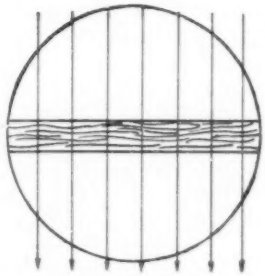
Same paper as "A", filled with oil or other fluid material, giving spaces between fibers same index of refraction as fibers. Reflection and refraction of light are reduced and paper becomes highly transparent. But transparency is not permanent because *fluids* "bleed" out.†

SAME PAPER
TRANSPARENTIZED THE ALBANENE WAY



Same paper as "A", filled with an inert synthetic resin, with correct index of refraction. This is how Albanene is made. Its transparentizer does not "bleed" out. Albanene holds its color and strength and is permanently transparent.†

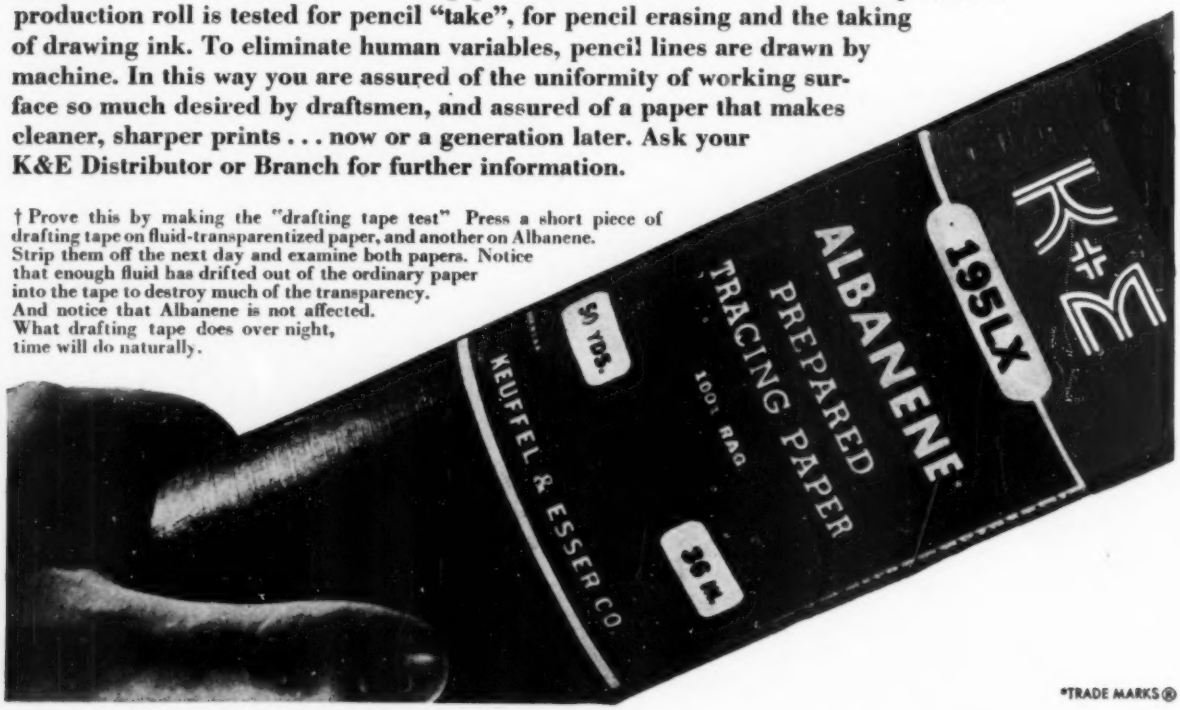
PAPER TRANSPARENTIZED BY
CRUSHING AND BEATING FIBERS



Papers are also transparentized at the mill by a "beating" process. The fibers are crushed, flattened and compacted. Reflection and refraction of light are reduced. But the process weakens the fibers and the strength of the transparent paper is low.

More than 15 tests are made during production of Albanene. For example, each production roll is tested for pencil "take", for pencil erasing and the taking of drawing ink. To eliminate human variables, pencil lines are drawn by machine. In this way you are assured of the uniformity of working surface so much desired by draftsmen, and assured of a paper that makes cleaner, sharper prints . . . now or a generation later. Ask your K&E Distributor or Branch for further information.

† Prove this by making the "drafting tape test" Press a short piece of drafting tape on fluid-transparentized paper, and another on Albanene. Strip them off the next day and examine both papers. Notice that enough fluid has drifted out of the ordinary paper into the tape to destroy much of the transparency. And notice that Albanene is not affected. What drafting tape does over night, time will do naturally.



*TRADE MARKS ®

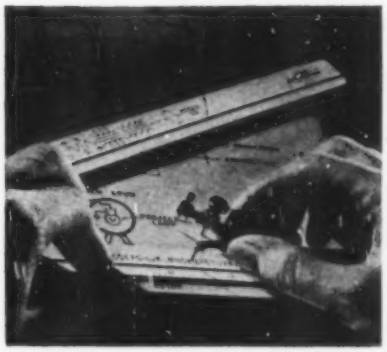
Transparent . . .
and Better!

AVAILABLE IN MANY FORMS FOR MANY USES

Albanene comes in 20-yard and 50-yard rolls in various widths and in three different weights. For those who like the convenience of cut sheets, a new Albanene package has been designed. It strongly protects the paper in shipment and storage, and may be opened without mutilating the container, thus serves as a dispenser in drafting room or stock room. Albanene cut sheets can be supplied imprinted to your specifications.

The Right Angle

Once you've discovered the pleasure of drawing on Albanene, the next logical step is to save time, trouble and eyesight with a K&E PARAGON* Drafting Machine. You control your calibrated straight edge with a light touch of one hand, for parallel lines and lines at any angle.

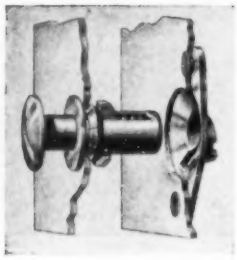


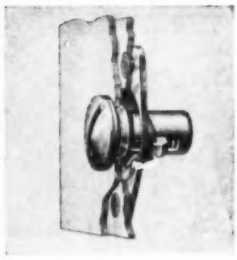
Make your lettering letter-perfect and save wear and tear on your nerves by using a LEROY* lettering outfit. Template grooves guide your pen so the finished result looks like printers' type, and the whole process is relaxing. There's a wide choice of sizes, styles and symbols.

K+E

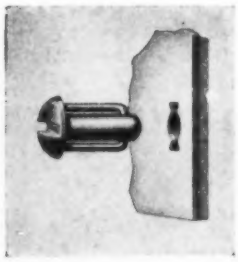
PIONEERS IN DRAFTING

3 ways to save on assembly costs

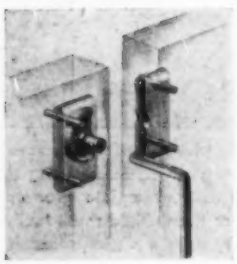




QUICK-LOCK For fastening removable access doors and panels. Because of its ease of installation, QUICK-LOCK is ideal for assembling removable panels. A 90° turn locks it in place. Stud is self-ejecting when unlocked; visual inspection shows whether fastener is locked. Spring loading takes initial load; solid supports carry increased load. Available in a wide range of sizes.



SPRING-LOCK One-piece fastener for blind holes has load-carrying steel spring wire. Spring steel arms lock fastener securely, prevent loosening under vibration. SPRING-LOCK will work with varying panel thicknesses, locks with a twist of the wrist. SPRING-LOCK is now available in high-impact plastic. The molded design permits heads to be made in various shapes for refrigerator shelf supports, washer knobs, brackets. Available in a wide variety of shapes and sizes, and also in custom designs.



ROTO-LOCK Serrated, tapered cam is engaged by formed lug as fastener is locked. Cam action draws panels together tightly, insures locking even under conditions of misalignment. Opens easily for demounting. ROTO-LOCK carries heavy tension and shear loads; can be used for air and water-tight seals; recesses completely into panels. Solidly built without springs or delicate mechanical parts, unaffected by arctic temperatures or field service.

Simmons Fasteners are widely used in refrigerators, washing machines, electrical equipment, electronic assemblies, prefabricated portable shelters, coolers, demountable furniture. Every Simmons Fastener is a service-proved design with a long record of assembly-cost saving in many industries.

If you are interested in cutting your costs, turn to Simmons Fasteners—the fasteners with *uses unlimited*. Write for samples and catalogs today.

SIMMONS FASTENER CORPORATION
1751 North Broadway, Albany 1, New York

Simmons

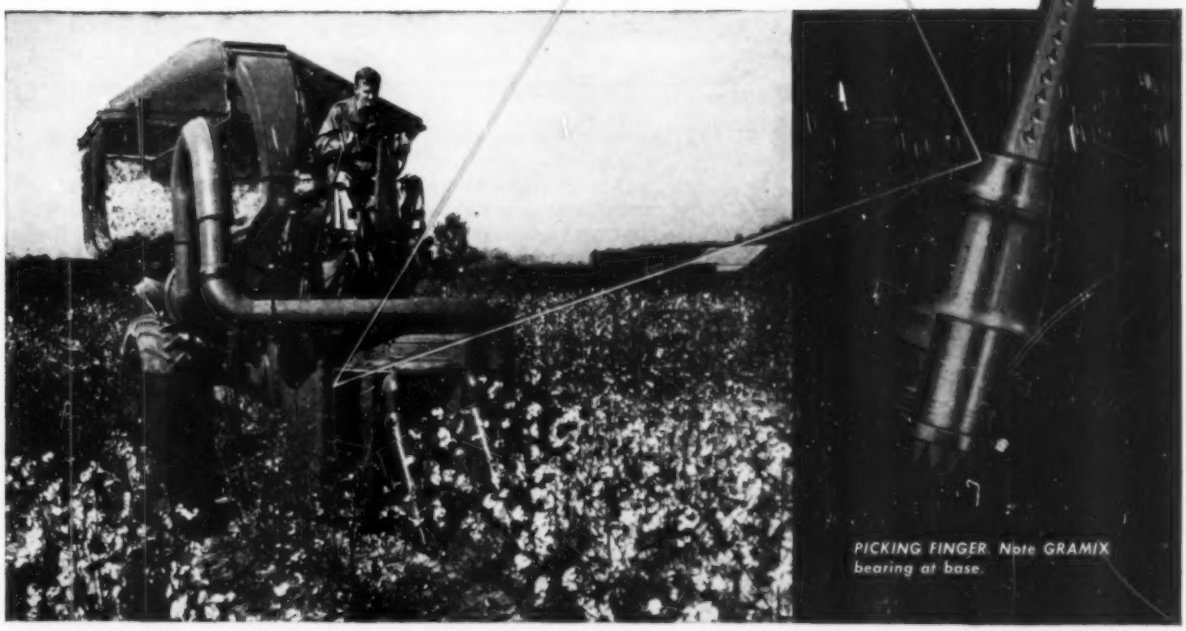
QUICK-LOCK
SPRING-LOCK
ROTO-LOCK

McCormick cotton picker uses GRAMIX® bearings

As one of International Harvester's big high-drum type McCormick Cotton Pickers moves down a row of cotton, 600 barbed picking fingers, rotating at speeds up to 2700 r.p.m.'s, pluck the cotton from the open bolls. And bronze GRAMIX bearings, on the barbed fingers, help make the successful operation of this ingenious picking device possible. This is typical of the way GRAMIX parts have helped improve many products and made the development of many other products possible. GRAMIX is produced from metal powders, compacted under pressures up to 70,000 psi and sintered at high temperatures to form strong, tough alloyed metal parts that will usually outperform and outlast parts produced by old fashioned machining methods. GRAMIX bearings and other specialty parts can be die-pressed into fairly intricate shapes with tolerances as close as .0005". They require little or no machining, thus saving man-hours of production time and greatly reducing scrap loss and waste. Because of their porous structure, GRAMIX parts require less metal and they can be oil-impregnated during manufacture to insure a constant oil film at the bearing surface. Chances are the special properties and characteristics of GRAMIX can help cut costs and improve the performance of your products. For complete information about GRAMIX, write us today.

GRAMIX bearings like this help the barbed fingers of the picking unit operate so efficiently in the amazing McCormick Cotton Picker.

95



PICKING FINGER. Note GRAMIX bearing at base.

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION • SAGINAW, MICHIGAN

What's Screwy? by Phillips

"Oh, he's not so smart. It's just that those Phillips Screws are so easy to drive."

PERFECTLY MATED! Only Phillips Drivers are perfectly mated to Phillips Screws. Look for the name Phillips on the shank.

EASE of driving is only *one* big advantage. Phillips Screws save time, work and money. They also add structural strength, set up tighter, resist the loosening effect of vibration. And they eliminate driver skids, damaged parts and split screw heads.

The identifying X on the cross-recessed-head identifies the x-tra quality of Phillips Screws instantly. Be sure to state "Phillips" on the specifications.

PHILLIPS *Cross-Recessed-Head* SCREWS

X marks the spot... the mark of extra quality

AMERICAN SCREW COMPANY • ATLANTIC SCREW WORKS, INC. • THE BLAKE & JOHNSON CO.
CENTRAL SCREW COMPANY • CONTINENTAL SCREW COMPANY • THE EAGLE LOCK COMPANY
ELCO TOOL AND SCREW CORPORATION • GREAT LAKES SCREW CORPORATION • THE H. M. HARPER CO.
THE LAMSON & SESSIONS COMPANY • NATIONAL LOCK COMPANY
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TODAY'S . . . AND THE FUTURE'S . . . FINEST FASTENER

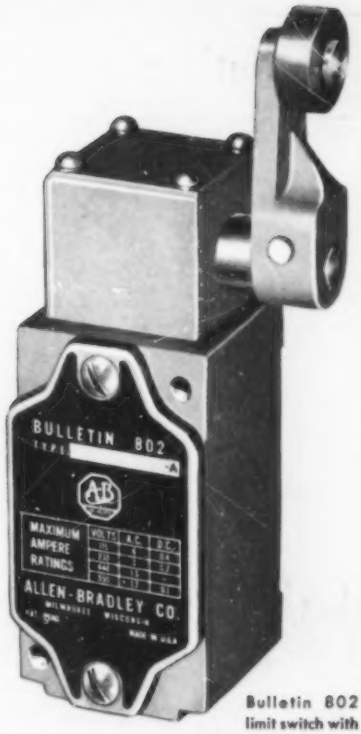
New OILTIGHT LIMIT SWITCHES

Here is a new line of remarkably compact Allen-Bradley limit switches . . . streamlined for fine appearance and built for millions of failure-free operations.

The operating heads of these limit switches may be attached to the switch body in four definite locations, each 90 degrees apart. A large selection of pushrods, lever arms, and other actuating mechanisms is available.

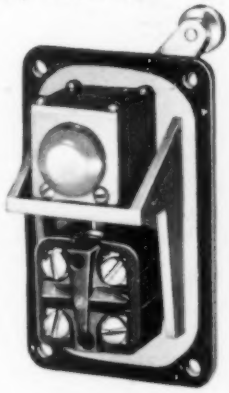
The name plate cover has a synthetic rubber gasket to exclude oil. Terminals are easily accessible by removing the cover plate. The body is threaded for ½" conduit. The switch mechanism is snap-acting, with one single pole normally open and one single pole normally closed contact, electrically separated.

The new Bulletin 802 limit switches are designed for machine tool applications. For further information send for a copy of Allen-Bradley Bulletin 802.



Bulletin 802 limit switch with roller lever

Roller lever type (Front View) for cavity mounting in machine frames



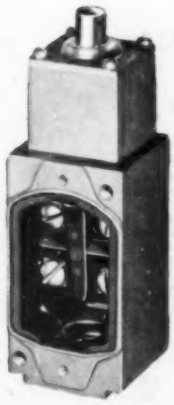
Roller lever type (Rear View) showing terminals for n.o. & n.c. contacts

ALLEN-BRADLEY
QUALITY
LIMIT SWITCHES

A-B Quality

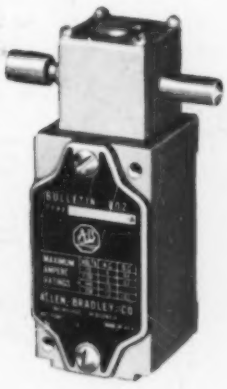
Allen-Bradley Co.
1316 S. Second St., Milwaukee 4, Wisconsin

Pushrod limit switch with roller for vertical motion of the pushrod



Pushrod limit switch without roller—cover off to show terminals

Pushrod limit switch designed for horizontal motion of the pushrod



Pushrod limit switch with side pushrod and maintained contacts

Lever operated limit switch with a long and flexible operating rod

1-53-MR

Extra! Handy Auxiliary Contacts

for all Allen-Bradley Sizes 0 and 1 Solenoid Controls

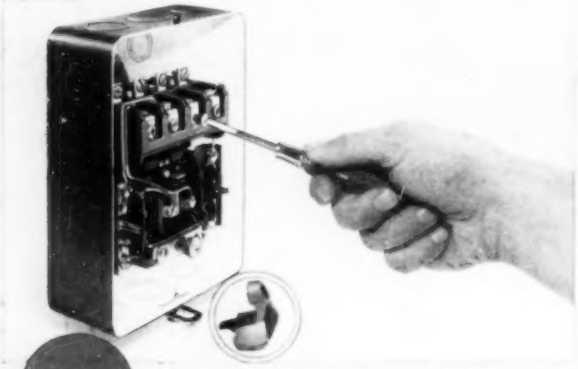
Contact may be reversed by removing one screw

Do you want to add one or more extra pilot contacts to some of your Allen-Bradley solenoid switches . . . to operate indicator lights, relays, or other starters?

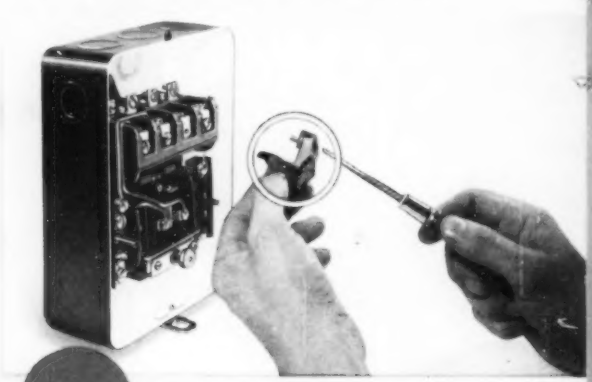
These new, compact auxiliary contacts can now be added to the arc hood of any and all standard sizes 0 and 1 solenoid switches. The operating arm of the auxiliary contact is actuated by the up and down motion of the solenoid plunger of the switch to which it is attached.

Write for descriptive literature.

SO SIMPLY APPLIED



First Remove the terminal screw from the stationary contact block of the Allen-Bradley starter.



Second Insert terminal screw into mounting hole of auxiliary contact to be attached to starter.

Then Screw terminal screw into stationary contact block and fasten auxiliary contact to starter.

Ready to Wire Allen-Bradley auxiliary contact is now ready to be wired for any auxiliary pilot circuit.

Auxiliary Contacts easily changed from n.o. to n.c. operation

The new Allen-Bradley auxiliary contact may be instantly changed from n.o. to n.c. contacts. Removal of one screw permits the instant reversal of the contacts in the contact block. There are no small parts to lose.

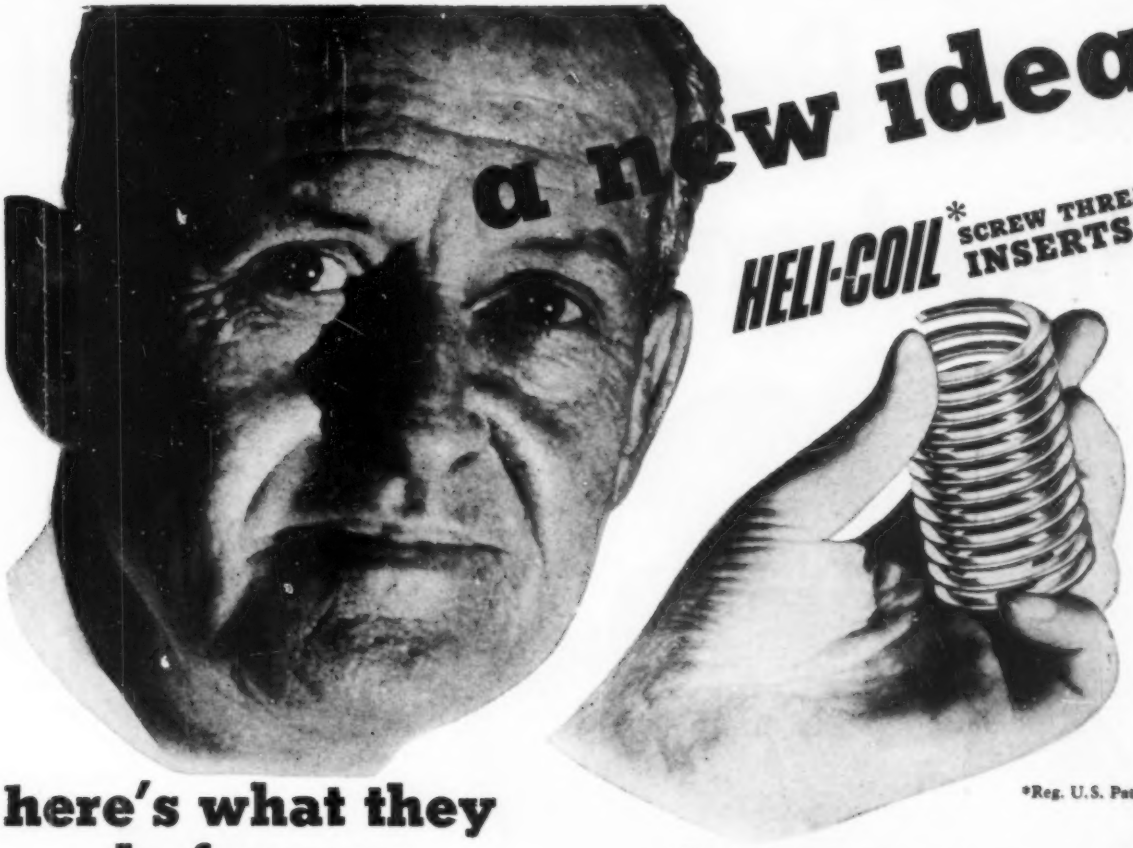
1-53-MR

These auxiliary contacts are available for all Allen-Bradley sizes 0 and 1 controls, including contactors, reversing switches, combination starters, Bulletin 709 solenoid starters, and Bulletin 609 manual starters.

Allen-Bradley Co., 1316 S. Second St.
Milwaukee 4, Wisconsin

ALLEN-BRADLEY

SOLENOID CONTROLS



*Reg. U.S. Pat. Off.

here's what they do for you

they save money because they strengthen threads and make *fewer* fastenings do the same holding job...they make *lighter* bosses and flanges practical...and they *save* weight in *two* ways: (1) by permitting use of cap screws instead of bolts and nuts or studs and nuts; (2) by putting smaller, shorter, fewer cap screws to work than required for unprotected threads.

they protect your product from thread wear and stripping for life in every kind of metal, in plastics or wood. They preserve your customer good-will by preventing complaints about thread failure.

they meet fast production line requirements...Simply drill and tap as usual, then wind in **Heli-Coil** Inserts for *permanent, armored threads.*

no other method is so simple, effective and practical—especially in aluminum and magnesium

So easy to use! Average time to install 3 seconds!

Drill...Hole is drilled in conventional way—right on production line. **Tap**...Hole is tapped with *Heli-Coil* tap to receive insert—right on production line. **Install**...Insert is installed in tapped hole with hand or machine inserting tool—right on production line.

What *Heli-Coil* Inserts Are

Heli-Coil Inserts are precision formed thread liners of stainless steel or phosphor bronze wire, diamond-shaped in cross-section. They are available for National Coarse, National Fine and Unified threads, pipe threads and aviation and automotive spark plug threads. They are made in all standard sizes and lengths for assemblies requiring Class 3, 3B, 2 or 2B fits.

APPROVED FOR ALL MILITARY AND INDUSTRIAL USES

These and many other advantages can mean much to you. Why not convince yourself about **Heli-Coil** *Inserts for your own benefit. Return the coupon now and get all the facts.*

HELI-COIL CORPORATION
141 SHELTER ROCK LANE, DANBURY, CONN.

☐ Please send *Heli-Coil* Catalog and Sample *Heli-Coil* Insert.

☐ Attached is drawing of our product. Where do you recommend using *Heli-Coil* Inserts?

NAME_____ TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE____ STATE_____ ©1964

Eaton Permanent Mold Gray Iron Castings—

for HYDRAULIC CONTROLS

Send for your free copy of the 32-page illustrated booklet: "The Eaton Permanent Mold Foundry." It tells the story of Permanent Mold Castings and takes you on a picture-tour of the Eaton Foundry at Vassar, Michigan.

EATON MANUFACTURING COMPANY
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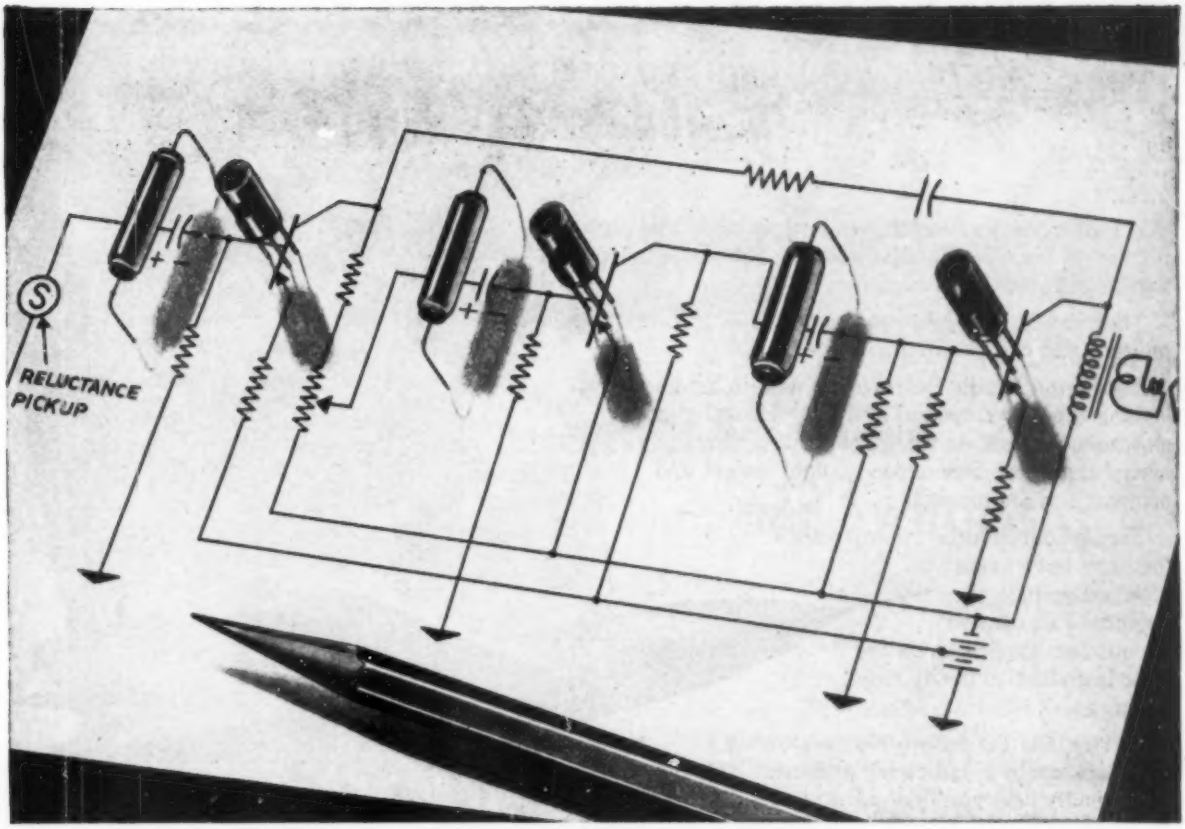


TRANSISTORS . . . TANTALYTIC CAPACITORS

teamed in 100-milliwatt tubeless amplifier

General Electric engineers at Electronics Park, Syracuse, have developed a new tubeless audio amplifier circuit that utilizes three junction transistors and three Tantalytic capacitors.

Although still experimental, this 3-stage amplifier promises significant advances in miniaturized equipments. It has a power output of 100 milliwatts—less than 10% distortion—and a power gain of 70 db.

Tantalytic capacitors were a "natural" for interstage coupling in the circuit because of their small size, large capacitance and low leakage current. They match the transistors in ruggedness and long operating life. And they will operate over a wide temperature range (−55°C to +85°C with at least 65% capacitance at −55°C). Other features include light weight, long shelf life, and hermetic sealing.

If you have a capacitor application where you need small size and superior performance, it will pay you to investigate Tantalytic capacitors. They're available in polar and non-polar construction and in ratings from 175 muf at 5 VDC to 12 muf at 150 VDC. For additional information use the convenient coupon below.

General Electric Company, Schenectady 5, New York.

General Electric Co., Section H407-313
Schenectady 5, New York

Gentlemen: Please send me a copy of your free Bulletin(s)

☐ **GEC-808 and GER-451 "Tantalytic Capacitors"**

☐ **ECG-1 "Germanium Transistors"**

Name _____

Company _____

Street _____

City _____ **Zone** _____ **State** _____

GENERAL ELECTRIC

Are space and weight savings vital?

here's how leading aircraft manufacturers get them with NEEDLE BEARINGS

Torrington Needle Bearings are integral design features in many leading aircraft because of their light weight and compactness coupled with their high rated radial capacity.

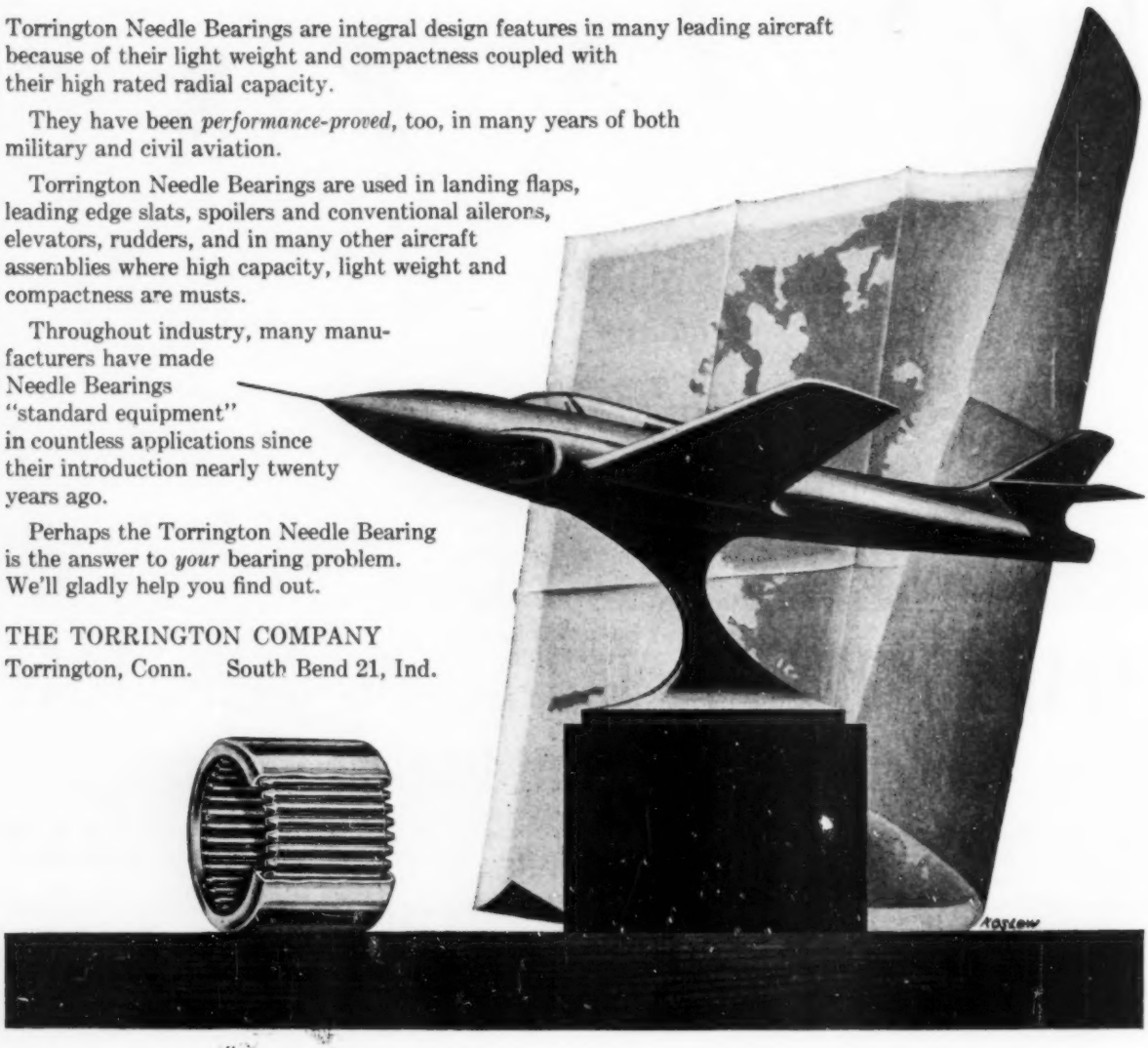
They have been *performance-proved*, too, in many years of both military and civil aviation.

Torrington Needle Bearings are used in landing flaps, leading edge slats, spoilers and conventional ailerons, elevators, rudders, and in many other aircraft assemblies where high capacity, light weight and compactness are musts.

Throughout industry, many manufacturers have made Needle Bearings "standard equipment" in countless applications since their introduction nearly twenty years ago.

Perhaps the Torrington Needle Bearing is the answer to *your* bearing problem. We'll gladly help you find out.

THE TORRINGTON COMPANY
Torrington, Conn. South Bend 21, Ind.

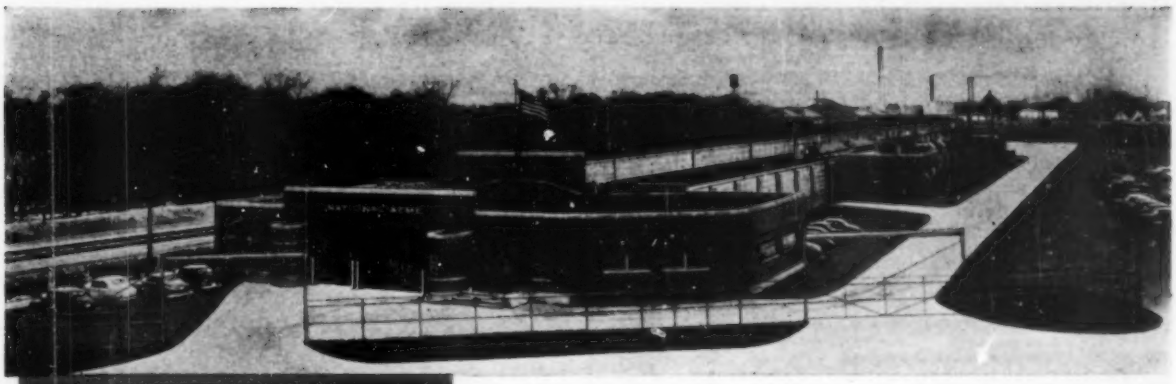


TORRINGTON NEEDLE BEARINGS

Needle • Spherical Roller • Tapered Roller • Straight Roller • Ball • Needle Rollers

Trade-marks of leading aircraft companies whose products enjoy the benefits of Needle Bearings.

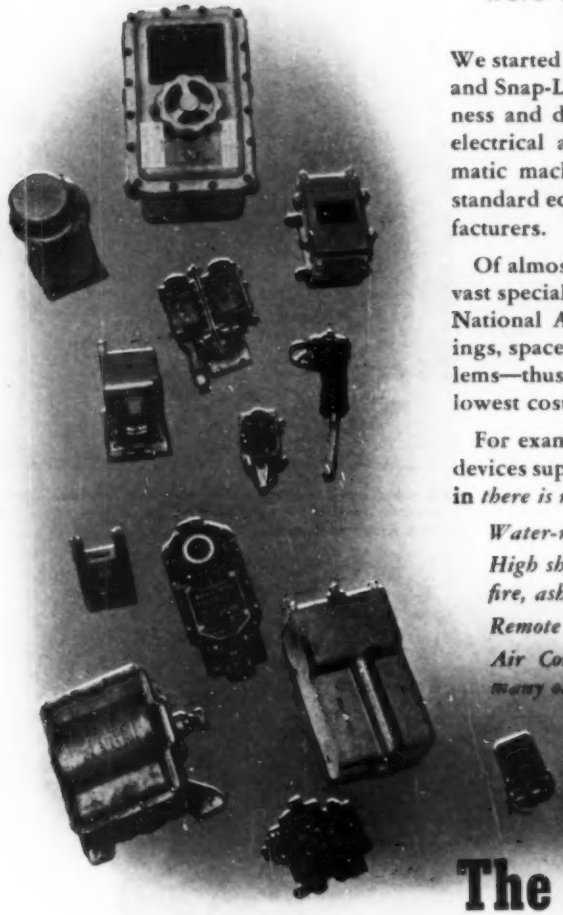
LOCKHEED · CONVAIR · BOEING · Cessna · Beechcraft · REPUBLIC AVIATION · NORTHROP · N A A · FAIRCHILD · BOULTON PAUL



THIS IS THE NEW 80,000-square-foot HOME OF SNAP-LOCK SWITCHES AND NAMCO "STELLITE"-WELDED SOLENOIDS. It is an expansion resulting from an ever increasing demand, from old and new customers alike, for the same high degree of switch and solenoid dependability which we require in the electrical and hydraulic circuits of Acme-Gridley Automatic Machines.

better Solenoids and Switches...

because our own engineers were **HARD TO PLEASE**



We started manufacturing Namco "Stellite"-Welded Solenoids and Snap-Lock Switches because of the high degree of ruggedness and dependability our own engineers demanded in the electrical and hydraulic circuits of our Acme-Gridley automatic machines. These devices have since been adopted as standard equipment by 85% of other large machine tool manufacturers.

Of almost equal importance to most of our customers is the vast specialized engineering experience available to them from National Acme—to help determine correct capacities, housings, space, type of mountings, and to assist with special problems—thus to insure the most practical applications at the lowest cost.

For example, here is just one group of switch and solenoid devices supplied to the Army, Navy and Aircraft services wherein *there is no room for failures.* These include:

Water-resistant, highly sensitive units for submarines.

High shock-resistant assemblies for synchronizing multiple gun fire, ashore and afloat.

Remote control switches for pin-pointing aircraft fire.

Air Conditioning and Refrigeration master controls—and many others.

Catalogs of Namco Switches (EM-51) and Solenoids (EM-52) explain the patented advantages of these lines. Ask for them — better still, if you have a problem, ask your engineers to consult ours.

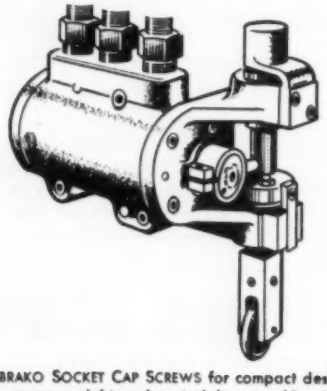
ELECTRICAL MANUFACTURING DIVISION

The NATIONAL ACME CO.

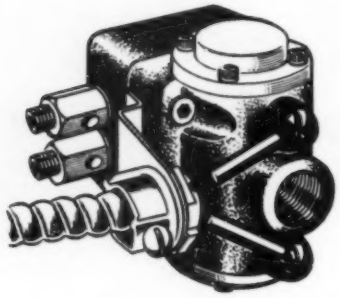
170 East 131st Street • Cleveland 8, Ohio

ACME-GRIDLEY BAR AND CHUCKING AUTOMATICS, 1-4-6 AND 8-SPINDLE—HYDRAULIC THREAD ROLLING MACHINES—AUTOMATIC THREADING DIES AND TAPS—LIMIT, MOTOR STARTER AND CONTROL STATION SWITCHES—SOLENOIDS—CONTRACT MANUFACTURING

UNBRAKO SOCKET CAP SCREWS have knurled heads for sure grip and fast assembly; accurate hex sockets for positive, nonslip internal wrenching; fully formed threads, Class 3 fit. They are made of heat treated alloy steel, with controlled fillet and continuous grain flow, for strength; and are available in standard sizes from #4 to 1" in a full range of lengths.



USE UNBRAKO SOCKET CAP SCREWS for compact designs to save space, weight and material on machine tools and metalworking equipment.



On textile machines, automotive equipment, electrical and electronic devices, and production machinery.

Do you really need a special UNBRAKO?

Before you specify a special socket screw, check UNBRAKO Standards. A standard UNBRAKO will do the same job much cheaper in most cases. You'll get better service and faster deliveries, because UNBRAKO socket screw products are stocked by your industrial distributor. Write for UNBRAKO Standards. SPS, Jenkintown 28, Pa.

UNBRAKO® SOCKET SCREW DIVISION

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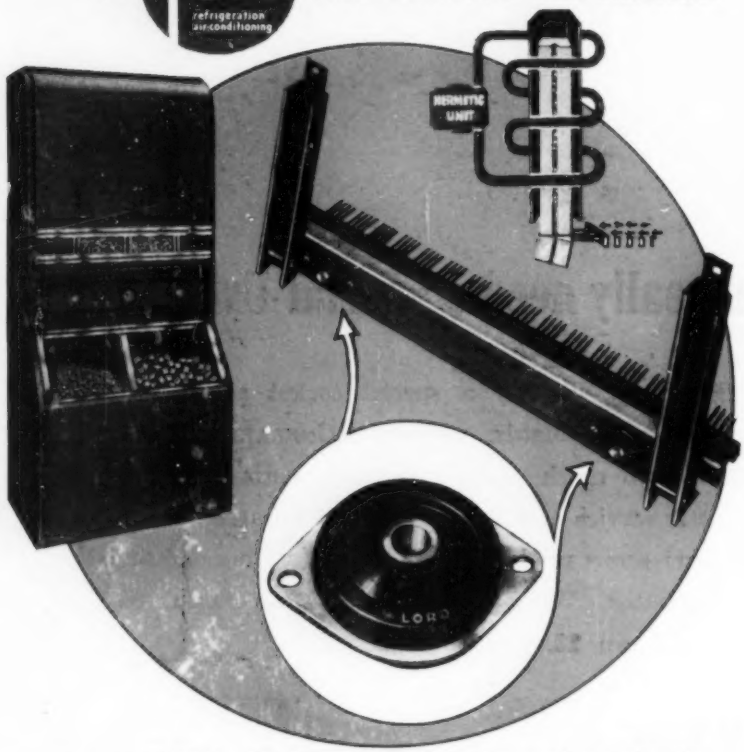
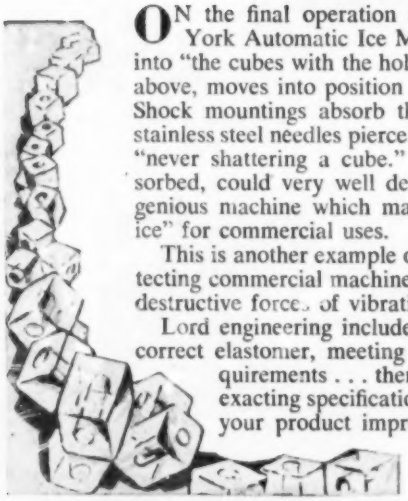
On precision instruments, dies, jigs and fixtures, and many other applications too numerous to mention.

UNBRAKO Standards—as listed in the SPS Catalog—are stocked by leading industrial distributors everywhere.

LORD Mountings Absorb Shock OF ICE CUTTING OPERATION IN York refrigeration air-conditioning AUTOMATIC ICE MAKER





ON the final operation of its ice making cycle, the York Automatic Ice Maker cuts the columns of ice into "the cubes with the holes." As the cutter bar, shown above, moves into position to cut the ice columns, Lord Shock mountings absorb the initial impact so that the stainless steel needles pierce the ice cleanly and evenly . . . "never shattering a cube." This shock load, if not absorbed, could very well destroy the "magic" of the ingenious machine which makes "Yorkubes" and "York-ice" for commercial uses.

This is another example of the vital importance of protecting commercial machines and their products from the destructive forces of vibration and shock.

Lord engineering includes the careful selection of the correct elastomer, meeting metallurgical and design requirements . . . then manufacturing mountings to exacting specifications. You are invited to discuss your product improvement program with us.

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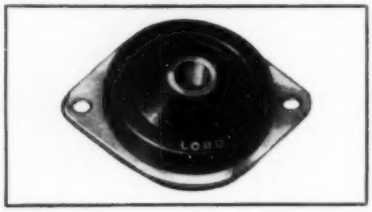
LORD BONDED RUBBER — *Headquarters for* **VIBRATION CONTROL**

(Advertisement)

Versatility of Lord Mountings Again Demonstrated by York Application

By correct use of the Lord Mounting to absorb initial shock of the stainless steel ice-cutting needles used in the final operating cycle of the York Automatic Ice Maker, Lord Engineering ingenuity demonstrates again its versatility. Lord Plateform Mountings, illustrated below, cushion the impact of the needles to eliminate the danger of shattering the "cube with the hole".



This is but one of a wide variety of installations in which Lord Mountings absorb shock and isolate vibration, protecting machine operation and prolonging service life.

On sensitive instruments and electronic equipment, Lord Mountings are used in a widely diverse pattern of applications. For instance, on airborne radio, radar and instrument panels Lord Mountings prevent vibration from affecting the accuracy of these sensitive mechanisms. Lord Mountings are also widely used on the recording instruments of industry, on farm and construction equipment, automotive and railway equipment.

Lord Flexible Couplings from 1/50th hp. to 100 hp. are used for the transmission of power. A tiny Lord Flexible Coupling transmits the power in home blenders and juicers. A mammoth capacity Lord Flexible Coupling transmits the power of the new Boeing Gas Turbine Engine to the driving wheels of a heavy duty truck, thus demonstrating another example of Lord "advanced design" engineering.

In the sky, on military and commercial aircraft, Lord Engine Mountings are used the world over from small single engine private planes to the military and commercial giants.

Over 27,000 different designs of Lord Mountings and their variations are available for reference in Lord data files. From this reservoir of design experience, Lord Engineers can help you improve your product.

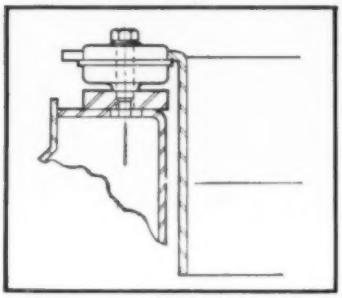
(Advertisement)

Lord Mountings Help Reduce "Down-Time" and Service on LeTourneau Earthmover

On "round-the-clock" operations on large construction jobs, "down-time" and service work become expensive to the contractor.

Of necessity, LeTourneau Earthmovers are operated under the most rugged conditions. It was found that rough terrain, rocks and other obstacles damaged radiators and water systems as a result of high shock loads exerted on those component parts.

Lord plate form mountings are now used on the top of the radiator in either horizontal or vertical position, according to the construction characteristics of various LeTourneau Earthmover Models. These are shown below.



The base of the LeTourneau radiator rests on the Lord plate form mounting illustrated below.

This combination results in complete control from any direction, of engine vibration and the heavy shocks encountered in earthmoving operations. Thus, the vitally important cooling system of LeTourneau heavy duty earthmoving equipment is protected by Lord Vibration and Shock Control Mountings. Thus, also, the costly servicing of cooling systems and the resulting "down-time" have been reduced to a minimum.

Further details on the isolation of vibration and absorption of shock loads in other industrial applications are available on request from Lord Manufacturing Company, Erie, Pa.

Protect Radiator on "D" Roadster Tournapull Earthmover by

R. G. LETOURNEAU INC

Wherever heavy machines change the face of the earth by moving tons and tons of dirt, it's a safe bet that the "D" Roadster Tournapull Scraper is doing a giant's job. Contributing mightily to its continuous, smooth, cool running are the Lord Vibration and Shock Control Mountings which protect the radiator from the shocks this rugged "bear for punishment" must withstand day in and day out. The "D" Roadster's Lord Mountings absorb the twisting, tearing strains of heavy duty earthmoving. The cooling system vital to its uninterrupted operation functions perfectly no matter how rough the going.

Lord Mountings are used profitably by machine designers to protect the most sensitive mechanisms . . . and the most rugged machines. In many instances Lord Engineers help to "design out" malfunctions in machines already operating in a wide diversity of industries. We welcome you to consultation with us on control of vibration and shock.

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LORD BONDED RUBBER

Headquarters for **VIBRATION CONTROL**

THEY SAY THAT SOME SHEAVES CAN EASILY BE MOUNTED IN ONE PIECE AND GIVE THE SAME SHAFT GRIP AS THE TWO-PIECE DESIGN
NO, CHARLIE... LISTEN- THE SHEAVE THAT GRIPS THE SHAFT TIGHTEST IS THE ONE THAT'S DESIGNED TO BE MOUNTED IN TWO PIECES!

FIGURE 1—TO MOUNT THE QD IN TWO PIECES you (1) slide the split hub on the shaft, (2) position it with the locking clamp-screw in the flange, (3) draw down on the set-screw over the key (QD exclusive) to prevent it from drifting, (4) slide the QD rim with its large taper bore opening up on the taper of the hub, (5) draw up on three heavy hex-head pull-up bolts for a tighter grip than you get with any other sheave.

FIGURE 2—TO MOUNT THE QD AS A UNIT where a Woodruff key is used in a shouldered shaft, you (1) locate the loosely assembled hub and rim of the QD sheave against the shaft shoulder and (2) draw up on the three heavy hex-head pull-up bolts. That's all there is to it. And you haven't sacrificed any grip on the shaft. For removal, you simply use pull-up bolts as jack bolts in specially tapped holes.

Let's settle this one RIGHT NOW!

You can't have your cake and eat it too.

A one-piece sheave assembly may grip the shaft sufficiently tight for average use, but it *won't keep the shaft key from drifting*. Your answer to this problem lies in an *exclusive* key set-screw in the hub of the *two*-piece Worthington QD* Sheave. The set-screw is tightened with the hub on the shaft before the rim is slipped on (figure 1).

Of course, if you use a Woodruff key in a shaft with a shoulder, drifting of the key is no problem and you then can mount the Worthington QD assembled in *one* piece *without any sacrifice of its famous friction-cone grip* (figure 2).

WORTHINGTON'S COMPLETE LINE OF MULTI-V-DRIVES includes QD sheaves in all sizes, QD Juniors and other fractional horsepower V-pulleys, as well as Worthington-Goodyear V-belts. Your distributor has complete stocks backed by the largest factory stocks you'll find anywhere. Write for Bulletin V-1400-B7F to Worthington Corporation, Oil City, Pennsylvania.

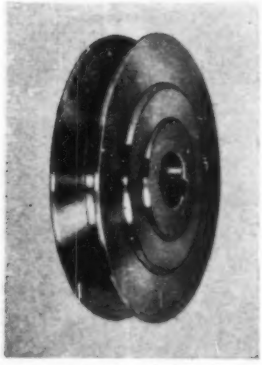
*Reg. U. S. Pat. Off.

The QD Junior V-Pulley for fractional-hp applications offers all the advantages of its big brother

TRADE MARK

Here's the popular Worthington QD principle applied to a fractional-hp V-pulley! It will grip the shaft tighter than any other V-pulley now available. The cutaway shows how tightening of the large nut causes the taper-bored rim to force the tapered hub *tight* on the shaft. Removal is just as simple.

No matter what your fractional-hp V-pulley needs WORTHINGTON has an answer . . .

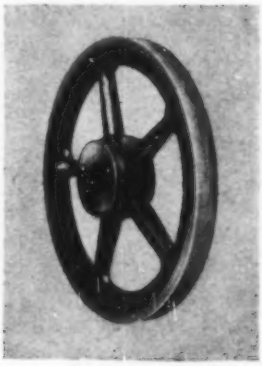


Machined Steel V-Pulleys —3½ in. and under

Precision-bored for proper fit on shaft. Belt seats properly, wears longer in accurately cut groove.

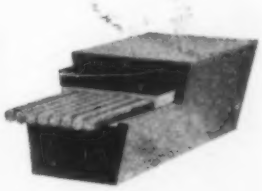
Pressed-Steel V-Pulleys

Heavy gauge, welded steel. Equal weight distribution assures accurate balance and vibrationless operation.



Cast Iron Bored-to-Suit V-Pulleys

Accurately machined for true running and perfect balance. Full range of sizes with one or two grooves.



For smoothest performance from V-belt drives use WORTHINGTON-GOODYEAR EC Cord V-belts

Each cord carries its equal share of the belt load, each belt—its equal share of the drive load. A complete line. Also steel-cable belts for high capacities, HY-T cord belts for high loads, and FHP belts.

GET MORE OF THE FACTS

For all the facts write today for: Bulletin V-1400-B7F on stock sizes and specifications of Worthington QD sheaves and Worthington-Goodyear V-belts. Bulletin FHP-100 on FHP pulleys and V-belts. Worthington Corporation, Oil City, Pa.

MV.2.13

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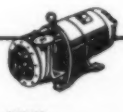
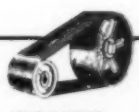


PUMPS: CENTRIFUGAL, ROTARY, STEAM, POWER



MULTI-V-DRIVES: QD SHEAVES AND V-BELTS

VARIABLE SPEED DRIVES: ALLSPEED DRIVE, ALLSPEED MOTOR DRIVE

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Multi-V-Drives

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Notice that the motor has no grease cups or fittings. It's pre-lubricated . . . needs no further lubrication. This means you can cramp it into close quarters, forget greasing channels and nipples brought to outside of machine. Just install it in "hard-to-get-at" locations and forget it! The way to grease a modern motor is *don't.*

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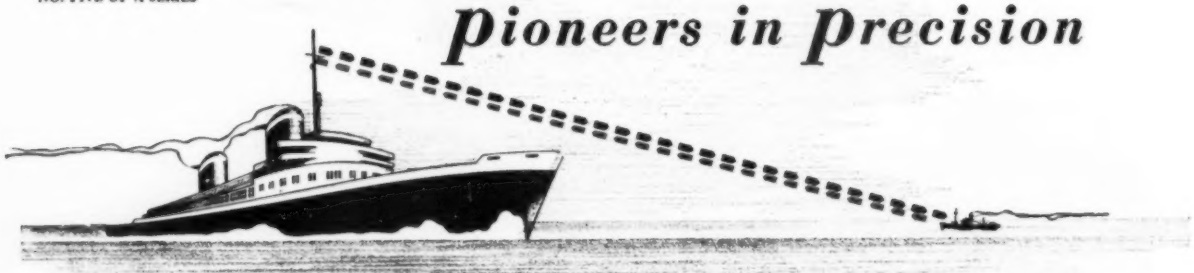

Actual photo of radar screen picture from ship in San Diego Harbor.

Raytheon Manufacturing Company, a division of which disclosed the world's first complete radar system in 1930. Pioneers in the development and perfection of magnetrons, the "heart" of all radar systems . . . the first to produce marine radar with 16" presentation. The "Mariners Pathfinder" radar, as installed on vessels of leading steamship lines, is a product of this world's largest producer of marine radar.

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More than a million **MPB** ball bearings have been supplied for many unusual operating applications – extreme temperature – shock – continuous high load capacity. The most extensive engineering knowledge in miniature bearing applications is available to you. Write for Catalog and survey sheet PE1

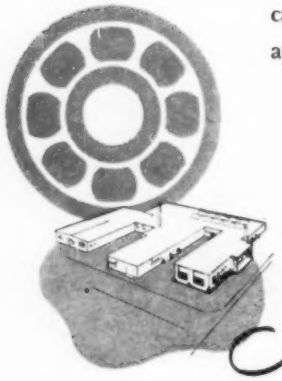

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Photo of Michigan Crane & Conveyor parts-loader in the Commonwealth Industries, Inc., plant at Detroit, by courtesy of The Iron Age.

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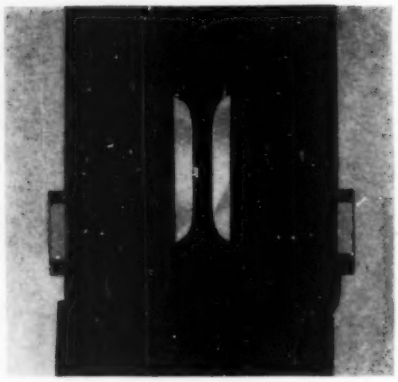
Below left—New wiring terminal
Below right—Plug-in contacts



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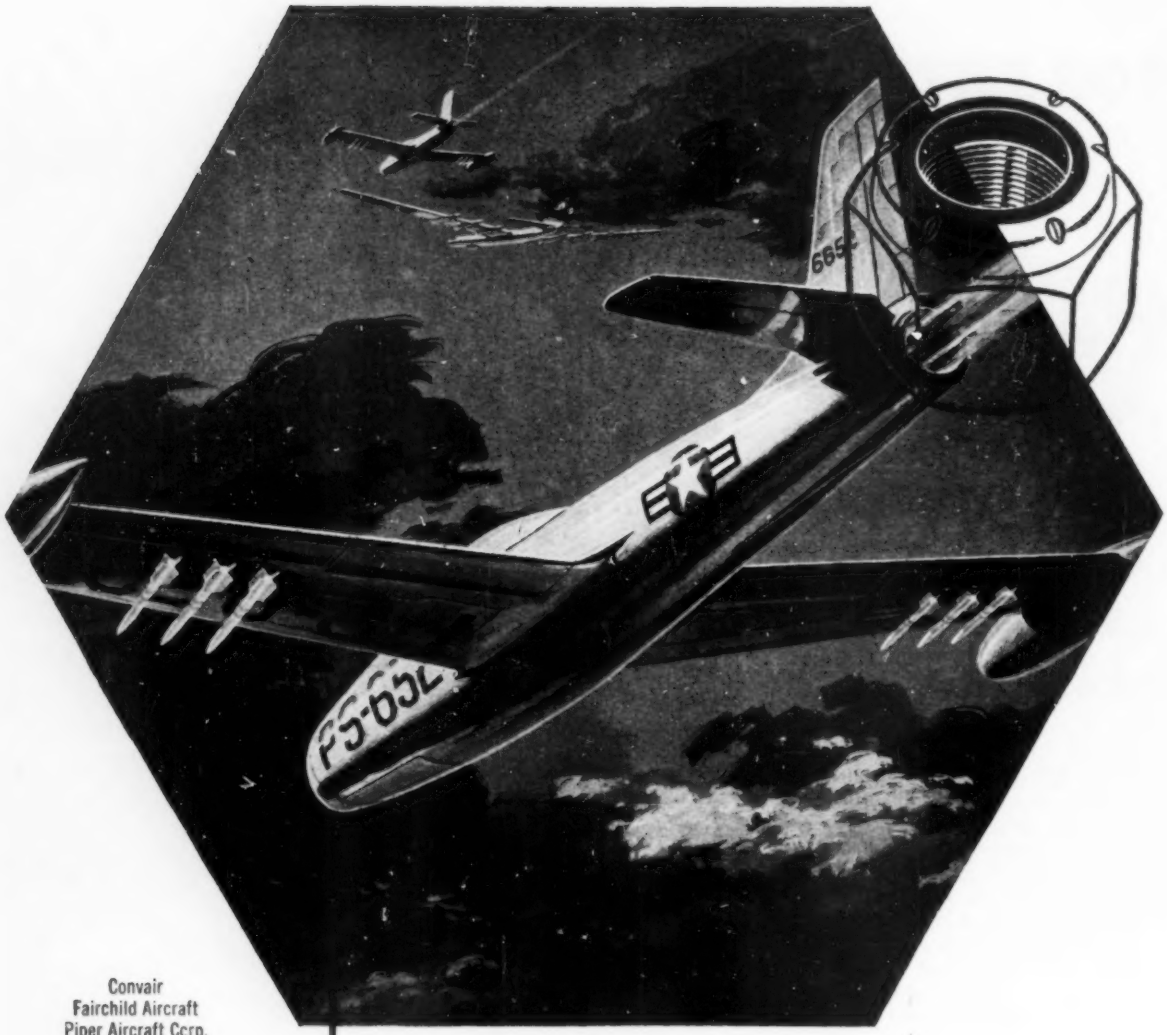

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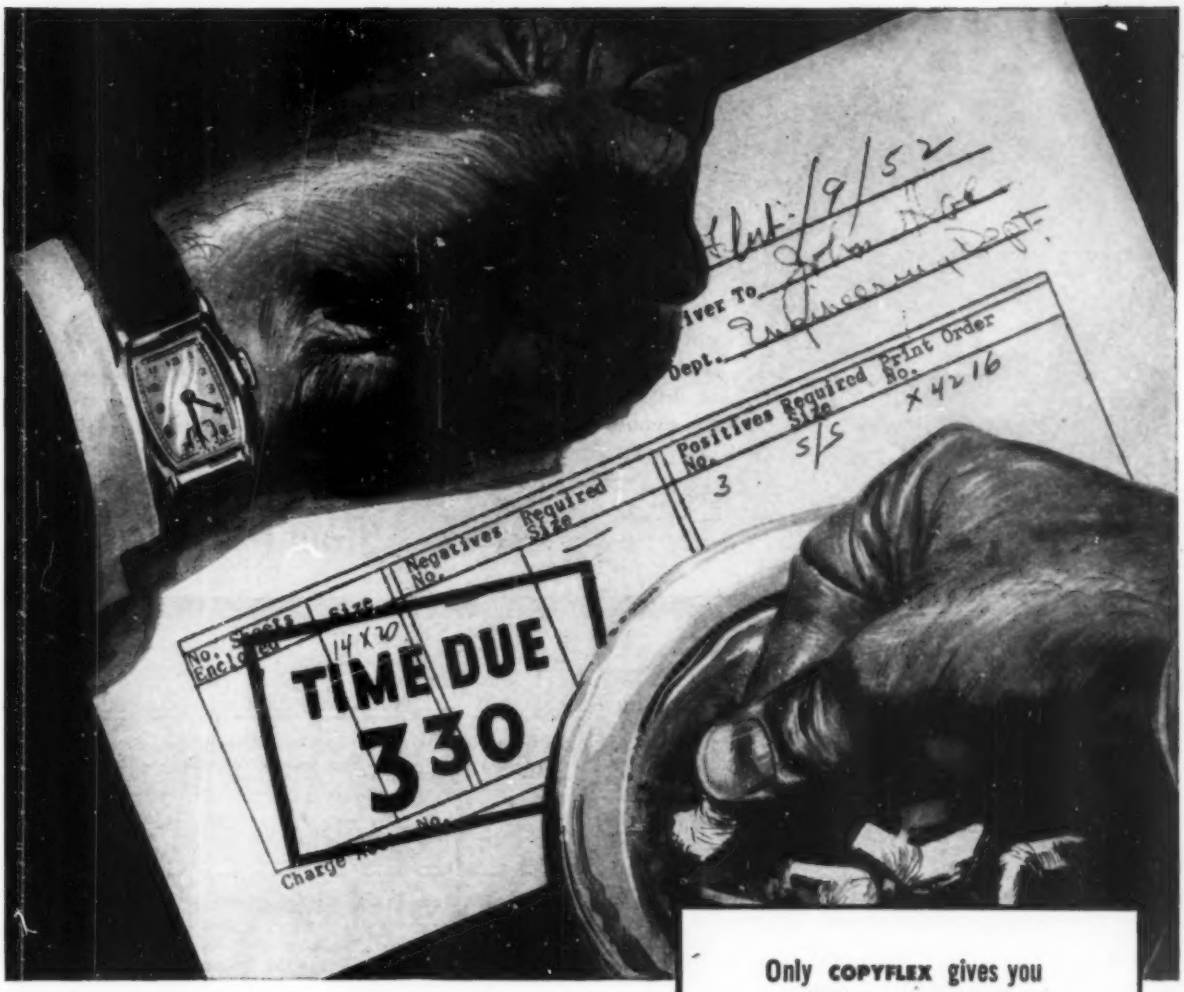

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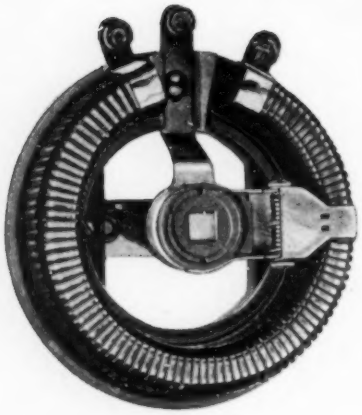
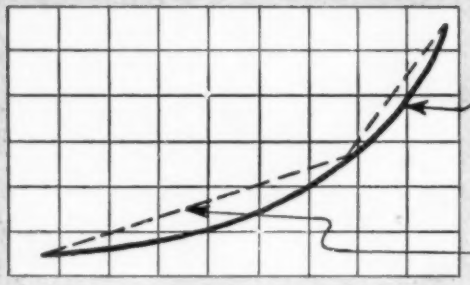


Exclusive Technique Means Longer Life... Smoother Resistance Curves for Mallory Power Rheostats

Superior tapered windings are produced by Mallory variable pitch winding techniques. A single diameter wire, with closely controlled variable spacing, is used instead of welded sections of different wire sizes. This exclusive construction produces the smooth curve shown in the chart below instead of the series of straight lines that only approximate a curve.

Expect more... Get more from MALLORY



Mallory variable-pitch winding produces a smooth resistance curve by controlled spacing of a single wire.

By avoiding the use of welded sections of different wire sizes, Mallory eliminates your problems of angular curves, bumpy action, hot-spots and wire breakage.

The hinged contact arm is another exclusive Mallory feature. It permits inspection and cleaning of the brush without affecting contact pressure. Constant contact pressure is maintained. Because the tension spring carries no current, there is no danger of its being annealed when the rheostat is overloaded. Springs are pre-set at optimum tension in relation to wire size and current rating.

Add up these Mallory advantages . . . point by point . . . and you can't help but ask for more details. Write or call us today for your copy of a new Technical Information Bulletin on Power Rheostats. The line includes seven power ratings from 50 to 500 watts, and a wide range of resistance values.

Data also available on JAN-Type Vitreous Enamel Resistors

Write for your copy of Technical Information Bulletin 76-2. It contains complete details of resistors that conform to specification JAN-R-26A for Types RW20 through 24 and RW29 through 47.

Television Tuners, Special Switches, Controls and Resistors

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P. R. MALLORY & CO., INC., INDIANAPOLIS 6, INDIANA

If you make hollow parts, we'll give you the hole

THE center hole's already in Timken® seamless steel tubing. There's less time wasted on machining; you get more parts from each ton of steel you buy because there's less scrap.

Often, finish boring's the first step—screw machine stations can be used for other operations. You get greater machine capacity without adding machines.

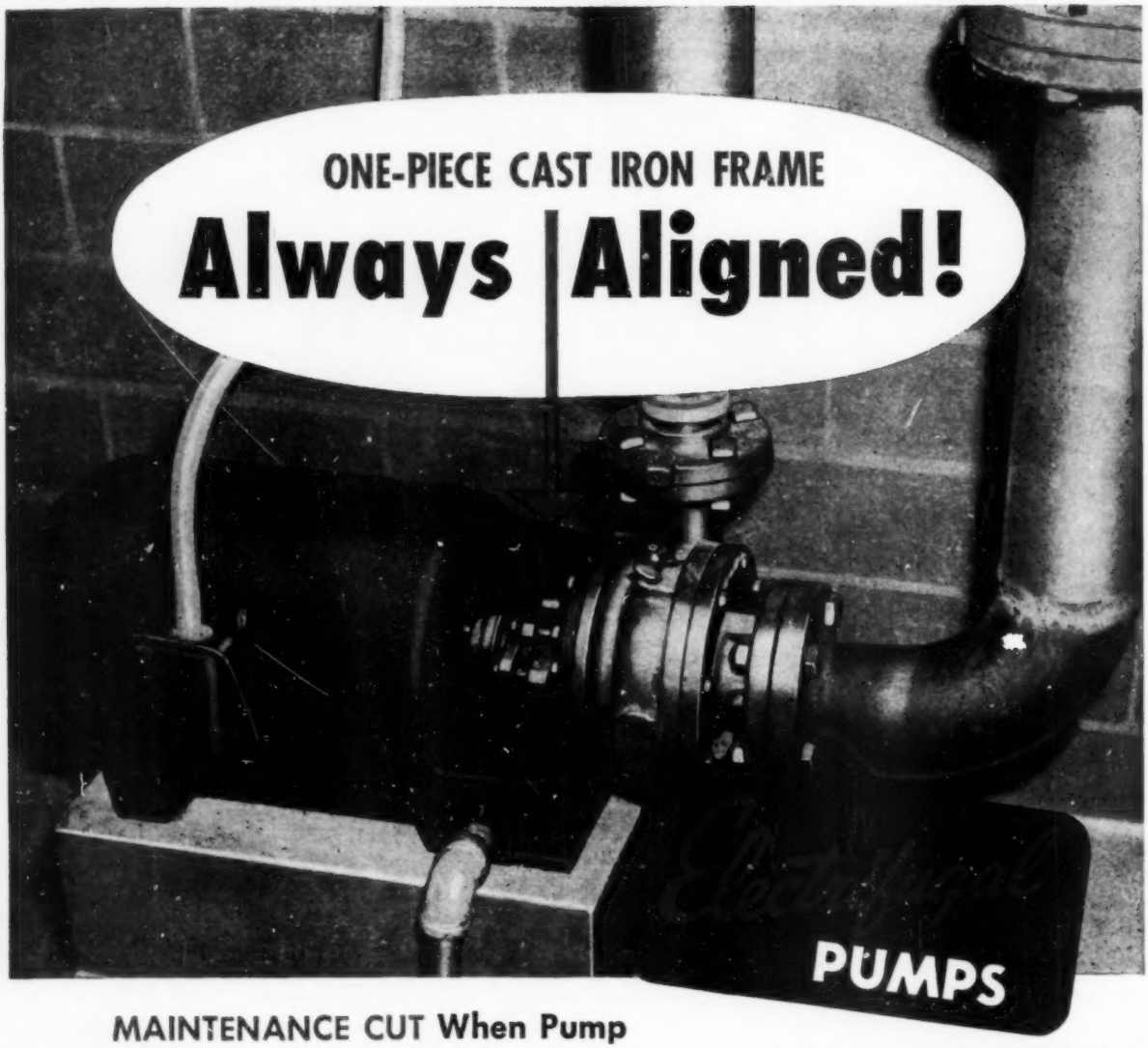
Higher quality in your product is assured because the piercing process by which Timken steel tubing is made is essentially a forging operation. The tubing has a uniform spiral grain flow for greater strength and a refined grain structure which brings out the best in the quality of the metal.

And to help you save even *more* steel, the Timken Company's tube engineering service will study your problem and recommend the most economical tube size for your job guaranteed to clean up to your finished dimensions.

For further information on the uses of Timken seamless steel tubing, write The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING



MAINTENANCE CUT When Pump and Motor Use Same Frame and Shaft

ELIMINATE TROUBLES caused by misalignment . . . excessive wear of bearings, packing, and couplings. For lower maintenance, standardize on Allis-Chalmers package pumps . . . the pump with permanent alignment built in.

The complete pumping unit comes to you in one piece. Simply bolt it to the floor, connect power and piping, and you're ready to pump. No special foundation, no couplings or extra parts required.

Both motor and pump are designed together . . . built together by Allis-Chalmers. And there's a nation-wide chain of Certified Service Shops to back up your installations. Built in sizes from 10 to 500 gpm; heads to 220 ft.

Call your nearby Allis-Chalmers distributor or district office. Or write Allis-Chalmers, Milwaukee 1, Wisconsin.

A-3872

Electrifugal is an Allis-Chalmers trademark.

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NEW PUMP FILMS

See new series of 3 sound-slide films, widely praised by educational and industrial groups. Get practical, instructive information on theory, application, installation and maintenance of centrifugal pumps. Series is designed for showing to maintenance meetings, plant groups, and engineering societies. Arrange now for a showing! Call your nearby Allis-Chalmers authorized distributor or district office. Or write Allis-Chalmers, Milwaukee 1, Wis.

Do you know that G-E Silicone Rubber is now available in MANY NEW FORMS?

G-E SILICONES FIT IN YOUR FUTURE

Considering silicone rubber for parts or equipment?

General Electric silicone rubber is now available in many new forms—forms which greatly increase your design possibilities. You're familiar with conventional molded and extruded parts fabricated from G-E silicone rubber, but do you know that silicone rubber is now being fabricated in the following forms?

conveyor belting	**sponged products**
ducting and hose	**coated cloths and tapes**
wire and cable	**bonded parts**

Proof? Note the variety of forms of G-E silicone rubber in the photograph!

Here are other important facts. G-E silicone rubber . . .
remains flexible from –100 F to 500 F . . .
is weather resistant . . .
resists chemical attack . . .
is 3 times stronger than early varieties . . .
does jobs no other rubber can do.

New free booklet available! If you haven't investigated G-E silicone rubber *lately*, why not get up-to-date details? Mail the coupon below. You will receive a newly printed, informative booklet describing the amazing properties of G-E silicone rubber and telling how you can put them to work. It's free. Just send the coupon.

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Waterford, New York

Please send me, free, your new booklet "Imagineering with Silicone Rubber." I am interested in G-E silicone rubber for:

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( ) Tapes and cloths ( ) Boots, sleeves, bellows
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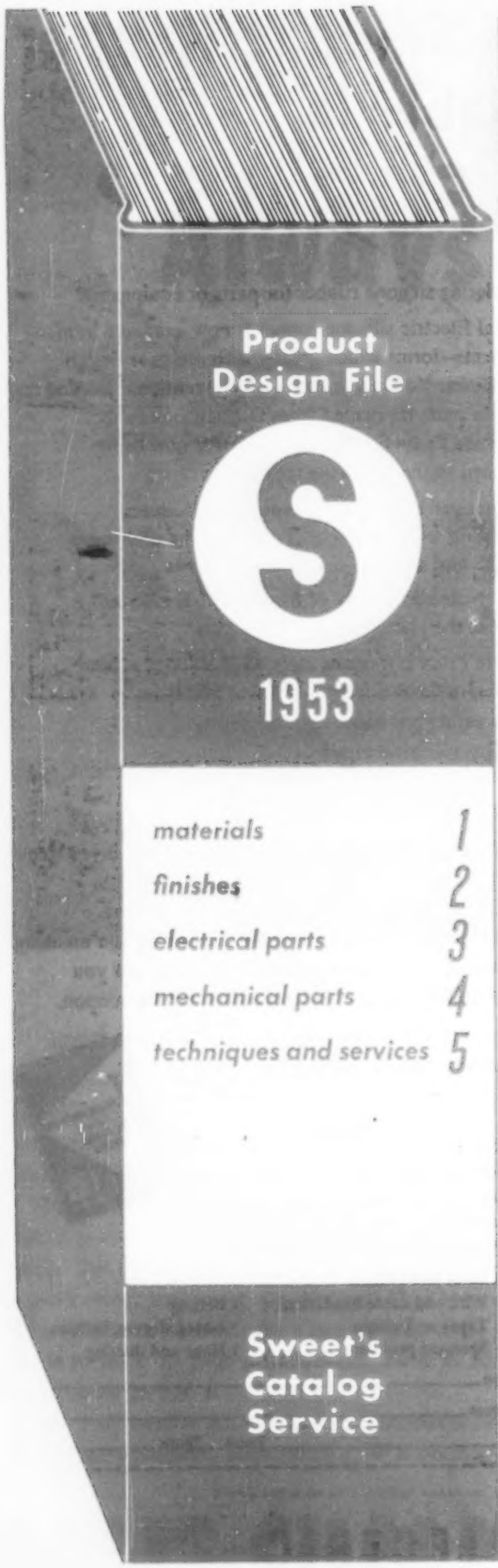
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All these manufacturers' catalogs are instantly available in Section 1a of your Product Design File. They contain comprehensive information on iron, steel, magnesium, aluminum, copper, nickel, platinum, gold, silver, palladium, and their alloys, in a wide range of forms.

The other sections of this File contain additional catalogs covering a wide range of materials and equipment . . . useful and up-to-date information on product forms, characteristics, performance and use.

This collection of 201 manufacturers' catalogs is grouped in sections according to products, or use of products, so that you can more readily compare one product with another. Indexes of manufacturers, products and trade names lead you quickly and easily to the catalogs you are looking for.

Sweet's is working constantly to get more manufacturers to send you their catalogs in this easy-to-use form. If you fail to find what you want, please tell us.

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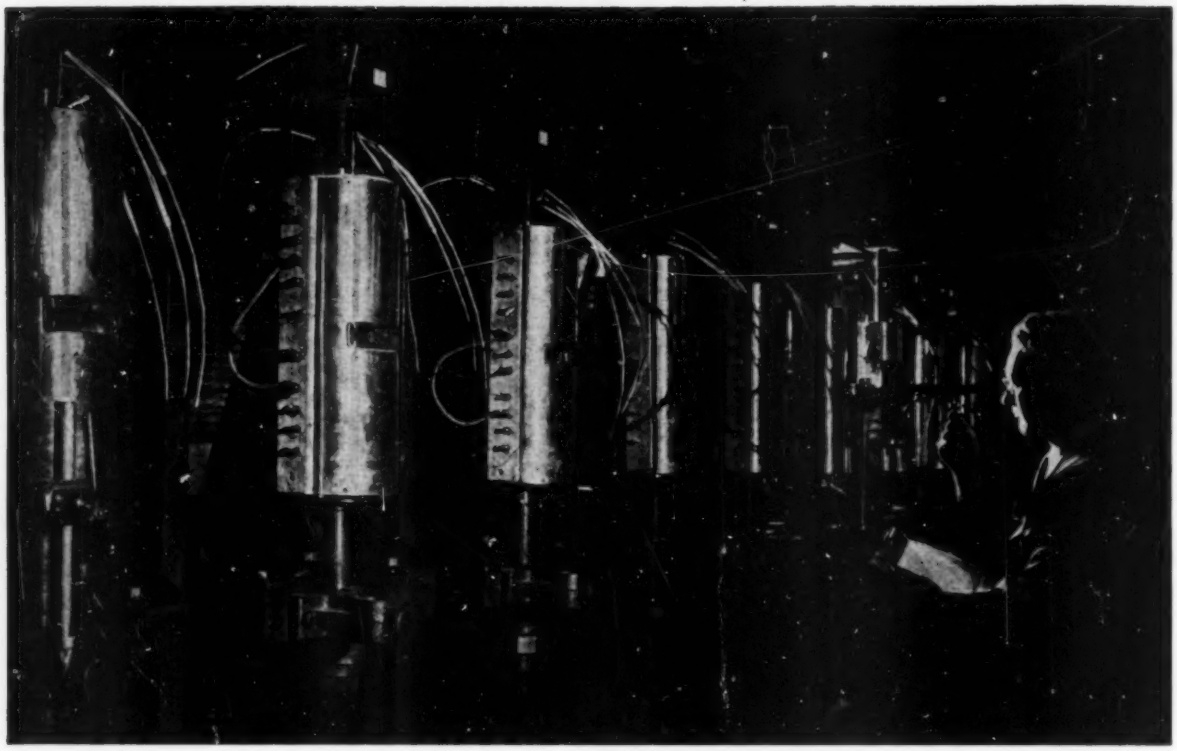


Where Metals Give Up Their Secrets

Suppose you want a metal to combat some particularly destructive set of service conditions.

Here's a man who can help you.

He's one of INCO's staff of engineering specialists and metallurgists. His primary responsibility is to determine how well a material qualifies for its intended use.

Often, he can find an answer to your problem among the metals and alloys he works with daily. He can tell you which of the INCO Nickel Alloys offers the most promising answer to your problem—and he can tell you just as frankly when a problem is outside the known scope of what the INCO Nickel Alloys can do.

Suppose, for example, you were caught in a predicament where you had to find a corrosion-resisting material with greater strength and hardness than you can get even in Monel®. He can name you an age-hardenable alloy that has the same excellent resistance as Monel *plus* mechanical properties you would expect to get only in a heat-treated alloy steel. Non-magnetic, too, down to −150° F. below zero. It is "K"® Monel, one of the INCO Nickel Alloys.

Maybe high temperatures complicate your problem. In that case he would study the service conditions and weigh out all the possible answers to your problem. Inconel "X"® is just one of a number of heat-resisting INCO Nickel Alloys that include Inconel®, the Nimonics, and the new Incoloy® — each one with different characteristics that make it best suited for different types of high temperature problems.

Remember this man. He can tell you where nickel alloys may safely be used to replace others containing even more critical metals. He can save you a lot of trial-and-error experimentation.

If you are wrestling with any problem that involves metals, let him lend a hand. There's no charge, no obligation. If one of the INCO Nickel Alloys cannot solve your problem, he may be able to recommend another metal that will. A note to "Technical Service" at this address will receive prompt attention:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

Inco Nickel Alloys

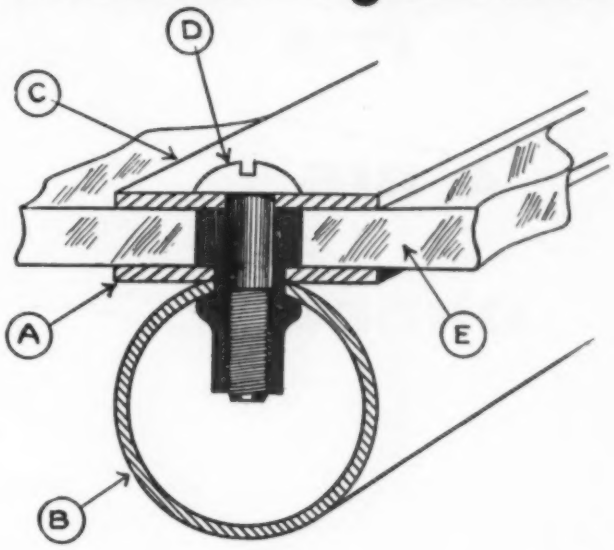
MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL "S"® MONEL • NICKEL
LOW CARBON NICKEL • DURANICKEL® • INCONEL® • INCONEL "X"® • INCOLOY® • NIMONICS®

B. F. Goodrich RIVNUTS fasten plastic to tubular post, make weather-tight seal!

TO PROVIDE a neat, tight seal for airplane windows, designers needed a simple, one-piece fastener—a blind rivet and nut plate combined. They found the ideal answer in a spacer-head B. F. Goodrich Rivnut.

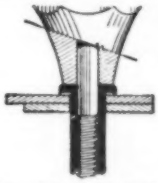
With the easy-to-use heading tool, one man quickly upset the Rivnut, securely riveted plate "A" to tubular center post "B". The firm bulge formed in the Rivnut shank conformed to the curvature of the tube. The Rivnut head served as a spacer for transparent plastic sheets "E". Screw "D" was then threaded into the clean, still-intact Rivnut threads to hold clamp strip "C" and plastic sheets in place.

Besides providing a tight, dependable seal, Rivnuts saved many man-hours on this job. If you're looking for a fastener which can improve your product and cut production time, why not get the facts from a Rivnut engineer? Write The B. F. Goodrich Company, Department PE-13, Akron, Ohio.

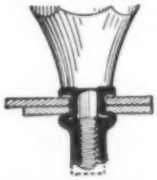


Rivnuts provide at least 6 clean threads in one simple operation!

1 Rivnut is threaded onto pull-up stud of a manual or pneumatic heading tool.



2 Rivnut is inserted—head firmly against work—tool at right angles to work.



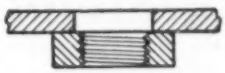
3 Tool lever operates pull-up stud, forming a bulge in the Rivnut shank.

4 After upset, Rivnut threads are still clean and intact, ready for screw attachment.

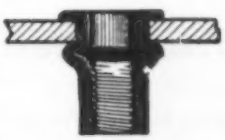
Compare these 4 methods of putting screw threads in thin sheet metal

Tapped—2 threads

Pierced and tapped—3 threads



Projection welded—4 threads



Rivnut—at least 6 threads

B.F.Goodrich

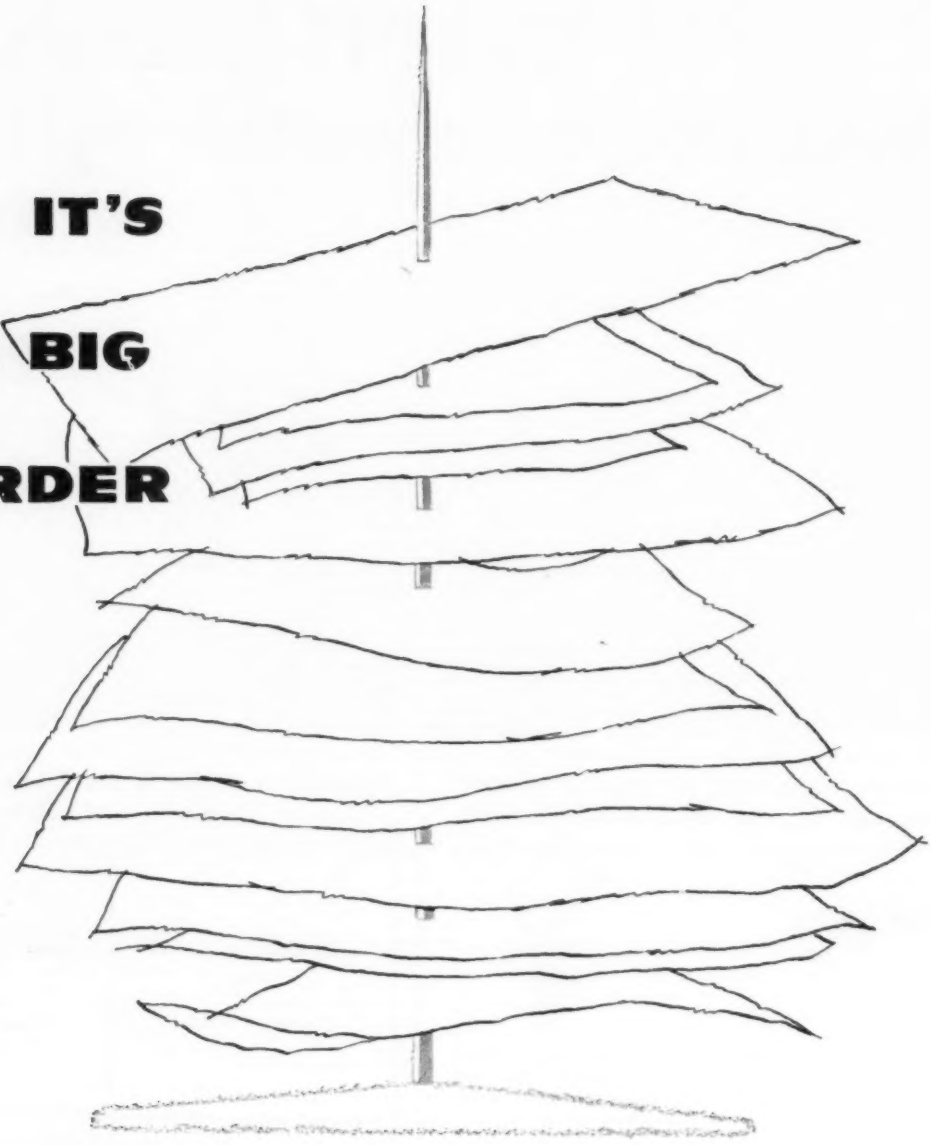
RIVNUTS

The only one-piece blind rivet with threads

SEND NOW FOR FREE RIVNUT DEMONSTRATOR

Shows with motion how Rivnuts work. Explains construction, gives proved applications. Write to The B. F. Goodrich Co., Dept. PE-13, Akron, Ohio.

IT'S A BIG ORDER



...and we're grateful

Thanks to you, we've just completed a wonderful, successful year, our sixtieth. Naturally, we're proud of this proof that Hyatt Roller Bearings have earned the confidence of so many leading manufacturers of all kinds of equipment. In the year ahead we will have the advantage of enlarged plants and new, additional facilities to help us fill the continually expanding demand for Hyatt quality bearings. We're grateful for your valued business of the past year and will be looking forward to serving you again in 1953 along with many new Hyatt users. Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey, Chicago, Detroit, Pittsburgh, Oakland, California.

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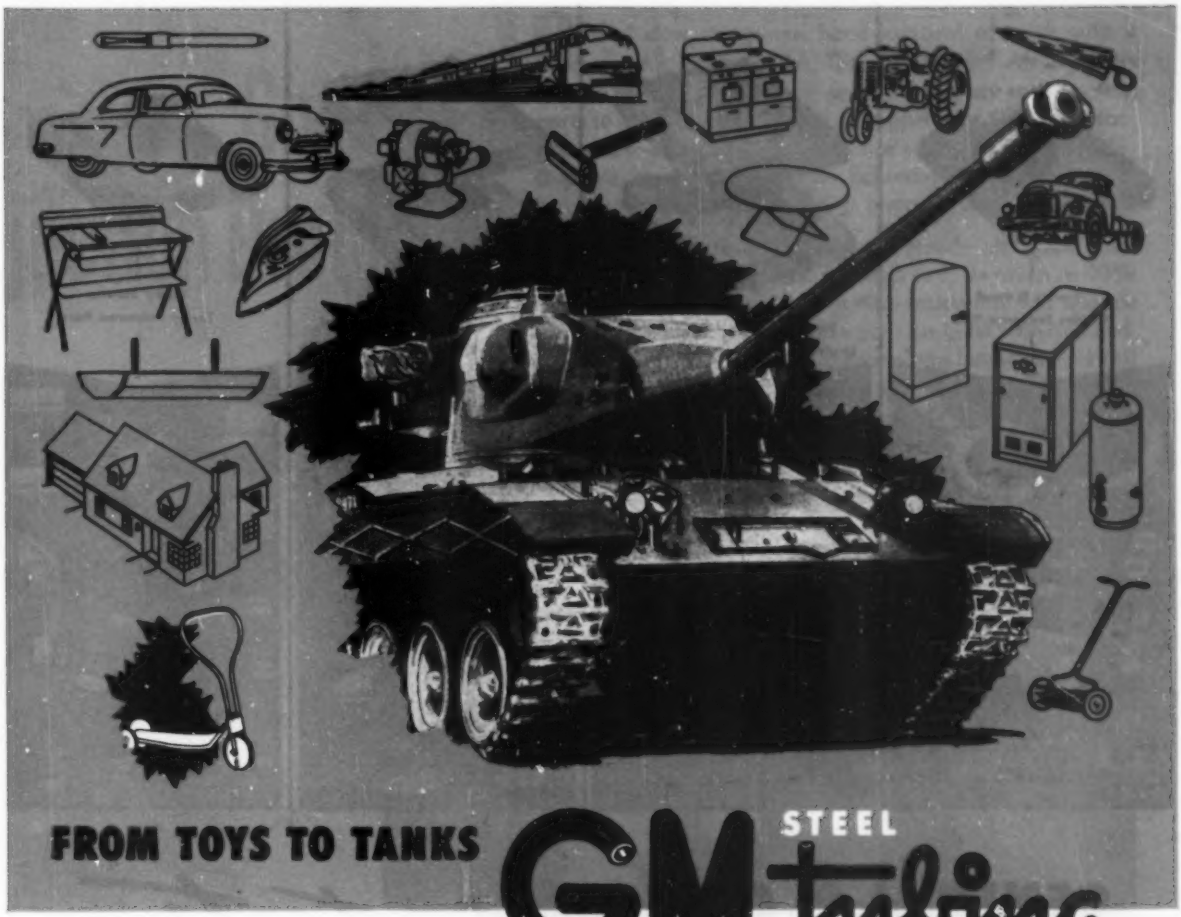

FROM TOYS TO TANKS

STEEL GM tubing

SOLVES PRICE AND PRODUCTION PROBLEMS

It's a far cry from a child's toy to a mighty weapon of war—yet GM Steel Tubing plays an important part in the design and building of both. In hundreds of other products, too, this low cost steel tubing serves to advantage either for the passage of liquids or gases, or as part of the mechanical structure.

Every day Rochester Products turns out *hundreds of miles* of GM Tubing in one of America's most modern and best equipped plants. Into every inch of its manufacture go the skill and engineering "know how" gained through nearly 20 years of General Motors research and development.

Whether you are designing new products or re-designing old ones, it will pay you to investigate the time-and-money-saving features of GM Steel Tubing.

WIDE RANGE OF SIZES AND FINISHES

GM Steel Tubing is available in welded single wall or copper brazed double wall construction, in sizes from ⅛" to ⅜" O.D., and in straight lengths or in 120′ to 1000′ continuous coils. Choice of plain, Terne coated, copper plated, or Fuse-Kote (copper fused) finish.

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GM Steel Tubing not only lends itself readily to intricate bending but also to all types of fabricating operations—crimping, beading, perforating, swaging, expanding, drawing, flanging, flattening, knurling, threading. Rochester Products offers complete fabricating facilities, including the services of experienced General Motors engineers.

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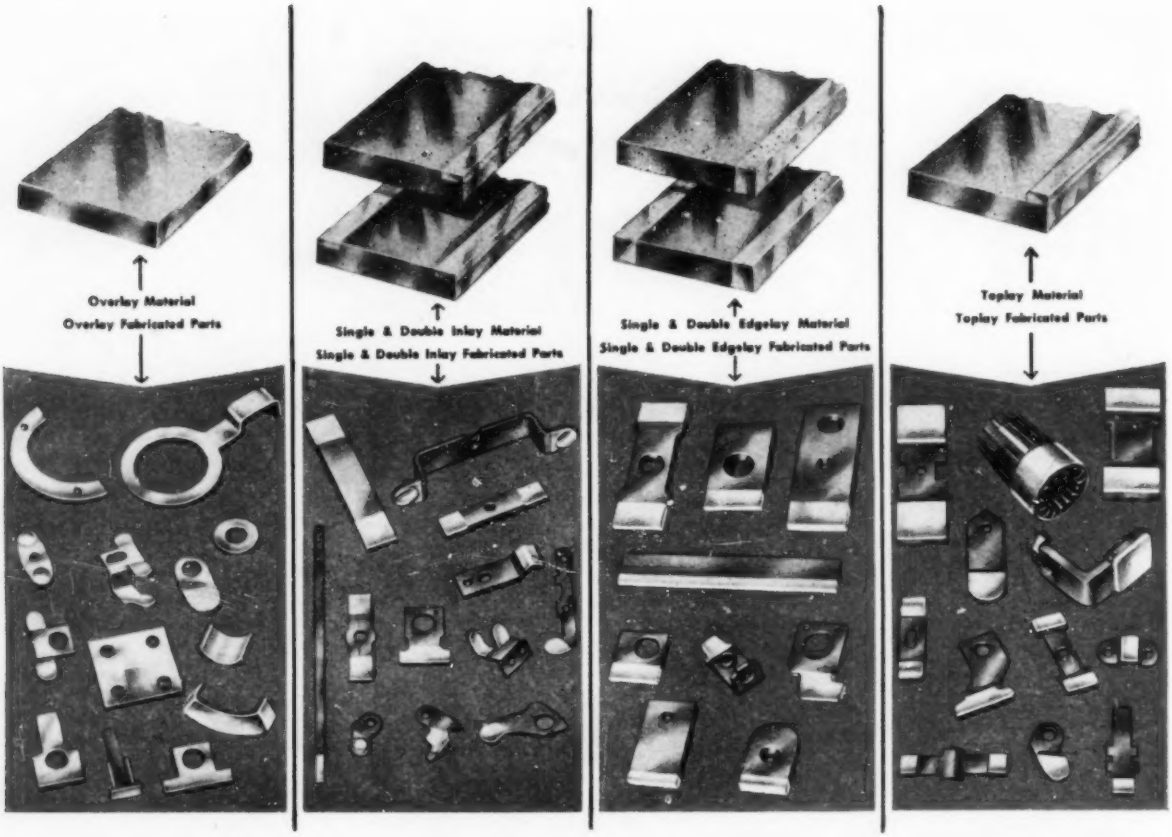
Our new illustrated brochure, entitled *"Look Ahead with GM Tubing,"* tells why GM Tubing is first in the field for lasting quality, adaptability and low cost. Send today for your free copy.

GM STEEL TUBING

ROCHESTER PRODUCTS *DIVISION OF GENERAL MOTORS*

Rochester, N. Y., U. S. A.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GENERAL PLATE *Composite Contacts* give the Solution to Your Contact Problems

General Plate is a source of supply for precious and composite metal contacts, buttons, rivets, contact assemblies and contact materials.

Contacts of solid precious metals are economical where a small amount of precious metal is used. In applications requiring larger contacts, General Plate composite metal parts offer better performance, longer operating life and reduced costs in comparison with solid precious metal types. These advantages are obtained by combining the physical and electrical properties of the precious metal with the greater strength and lower cost of the base metal.

General Plate produces overlay, inlay, edgelay and Top-Lay contact materials by bonding a precious metal layer or stripe to practically any malleable base metal. Composite contact materials make it possible to manufacture complete contact assemblies to close tolerances by simple blanking and forming operations.

General Plate's Contact Department is completely equipped to produce blanked and formed parts of solid or composite metals, buttons, rivets, and brazed, welded or staked assemblies . . . fabricated to exact specifications. By letting General Plate fabricate your contacts, you eliminate costly fabrication problems, needless equipment costs and problems of scrap disposal . . . contacts and/or assemblies are shipped to you ready for installation.

Write for complete information and Catalog PR700 today.

Have You a Composite Metal Problem?
General Plate can solve it for you

METALS & CONTROLS CORPORATION
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Give Your Ejection Problems the Air

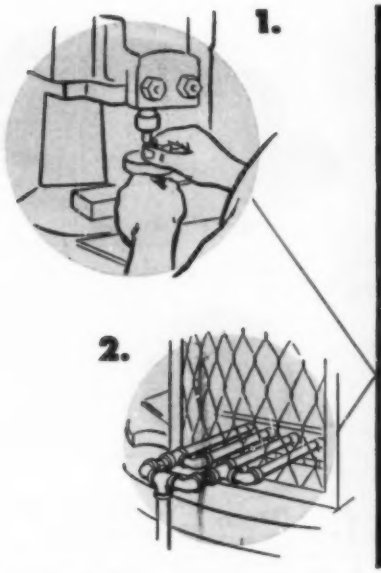
...and boost production and safety

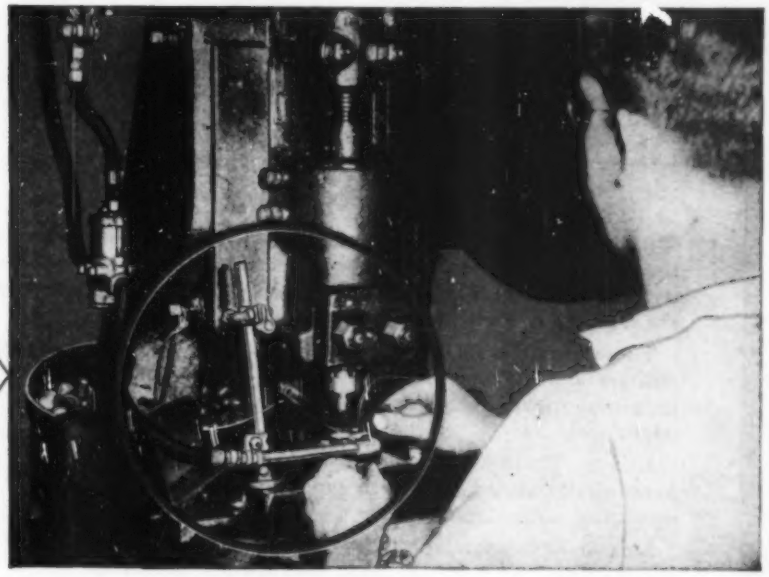
1 End slow, dangerous hand removal of work with a Schrader Air Ejection Set. Install Schrader Air Ejection Sets on your power presses—or any machines with moving parts to actuate a cam or sliding tripper. You'll find production soars—up to 100% . . . operator safety is boosted 50%. Replace hand removal with Schrader Air Ejection and watch your presses take a new lease on life.

2 Replace wasteful, homemade steady air blasts with Schrader Air Ejection Sets. Air costs drop as much as 90% because Schrader Air Ejection Sets ration out *just enough* air to do the job . . . synchronize your air blast with demand. Before you decide your old compressors have reached full capacity, check with Schrader to see how to cut air waste.

Schrader Air Ejection Sets are delivered fully assembled and ready to go to work. Their low cost is more than repaid in just a few weeks.

See how Schrader Air Ejection Sets will help you plan more effective use of machines. Write, describing the machines on which their use is contemplated—or fill out the coupon below.





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What's your temperature control problem . . . low and high limit controls, full delay switches, tube and rectifier cooling, fan switches, temperature control . . . Klixon Thermo-Snap Controls are meeting the requirements for these and other applications, daily.

These versatile thermostat controls are widely used in both military and civilian products ranging from airplanes, tanks, industrial apparatus, furnace fans to unit heaters and domestic appliances.

Klixon Thermo-Snap Controls are available in many hermetically sealed and open types in a wide variety of operating temperature ranges.

Klixon Engineers, specialists in temperature control applications, can help you solve your specific problems. Write for their help or further information.

KLIXON

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Division of Metals & Controls Corporation

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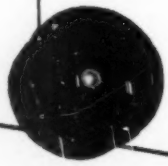


KLIXON MOTOR PROTECTORS PREVENT MOTOR BURNOUTS

To keep motors operating longer, specify and use motors with built-in Klixon Protectors. Built-in by the motor manufacturers, they prevent motor burnouts by cutting "off" the power should the motor become dangerously overheated. When it cools to safety, the protector snaps the power "on" automatically if the "automatic reset" is specified . . . or by pushing the red button when the "manual reset" type is used.

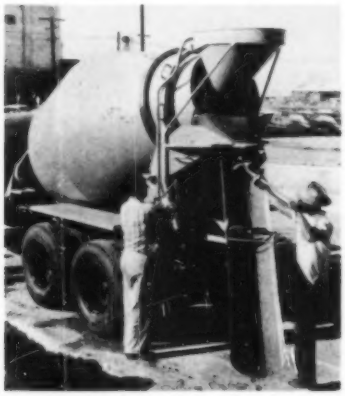
New facts for your file on U·S·S HIGH STRENGTH STEELS

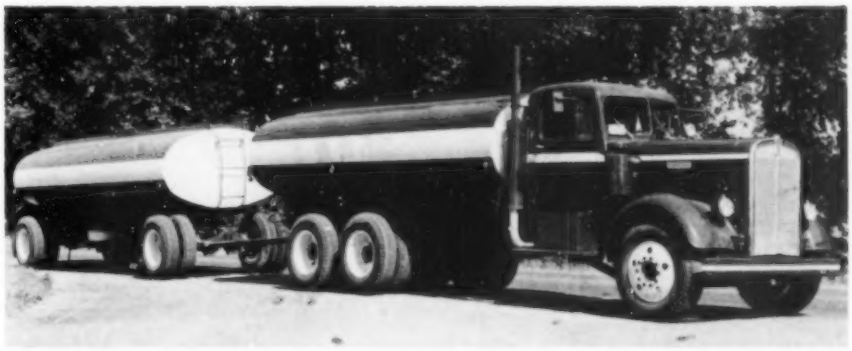
Here U·S·S COR-TEN steel reduces weight 1500 lbs. saves $725 per year in hauling costs.

Builder of concrete mixers has good reasons for using U·S·S COR-TEN steel construction

"We prefer U·S·S Cor-Ten steel," says Mr. Ross Castendyck of the Challenge Manufacturing Co., Maywood, Cal., "because of its superior corrosion and abrasion resistance as well as its high strength. These permit us to reduce our Mixer weight 10% to 15% and at the same time make it possible to build a 20% stronger unit that will stay in service at a lower maintenance cost."

We will be glad to show you how this superior high strength steel can be most economically applied to make your equipment more durable and more efficient.





By using U·S·S Cor-Ten high strength steel in lighter gages, in place of carbon steel, the Beall Pipe and Tank Corporation, Portland, Oregon, has reduced tank weight in this 8100 gal. unit by three-quarters of a ton.

The 242 gallons of gasoline that ride in place of the 1500 lbs. of steel saved, are hauled at no extra cost. Each of these free-riding gallons provides about $3.00 per year *extra* revenue—a saving in delivery costs that totals $725 annually.

In addition, the lighter weight of this equipment pays off for the operator in lower license fees, in reduced fuel consumption, in less wear on brakes and tires, less wear on the vehicle itself. And because U·S·S Cor-Ten steel has 4 to 6 times greater resistance to atmospheric corrosion than plain steel, and is more resistant to load surge and road vibration, this equipment will stand up better and cost less for maintenance and repairs.

These savings are typical of lightweight construction with Cor-Ten steel and they are practically all clear profit. That is because U·S·S Cor-Ten steel construction saves weight at lowest cost—sometimes costs no more than heavy carbon steel construction.

By using U·S·S Cor-Ten steel to reduce weight, the equipment builder also benefits. For by saving *weight*, he *saves steel* which makes his steel supply go further. That's important anytime—but especially important now.

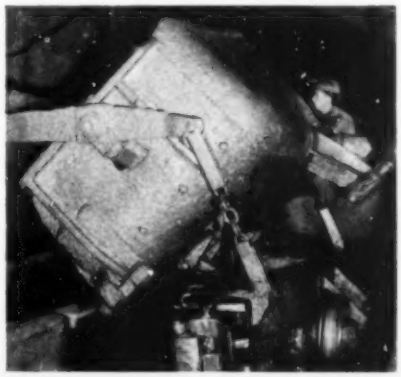
WHAT IS U·S·S COR-TEN HIGH STRENGTH STEEL?

U·S·S Cor-Ten is a ductile, low-carbon chromium-nickel-silicon-copper-phosphorous steel having a yield point of 50,000 psi min., and a tensile strength of 70,000 psi min. in thicknesses ½" and under.

Its resistance to abrasion and shock is superior to structural carbon steel; its fatigue resistance—that is, its ability to withstand repeated stresses—is 60% greater.

What particularly distinguishes U·S·S Cor-Ten steel is its unusually high resistance to atmospheric corrosion—4 to 6 times that of plain steel, 2 to 3 times that of copper steel. This property helps to assure the long life and low maintenance cost of any equipment, subject to rusting, in which Cor-Ten steel is used, whether to obtain greater durability or to reduce weight.

U·S·S Cor-Ten steel is produced in all standard products—plates, shapes, bars, sheets, strip, special cold-formed sections and wire. Recommended particularly for application in light and intermediate thicknesses.



29,725 mine cars have been built with U·S·S COR-TEN steel

Why? Simply because U·S·S Cor-Ten steel gives equipment the stamina to stay on the job. Witness this mine car, one of 22 built by C. S. Card Iron Works Company and put into service in 1941 in a western copper mine.

Though designed to be used with a 12" grizzly, the cars were loaded from a 24" grizzly handling chunks of very abrasive ore twice as large as they were designed for. Despite this and after operating eleven years under highly corrosive conditions, the cars are still on the job and ready for more service although each car has handled more than 85,000 tons of ore.

With tougher, stronger Cor-Ten steel not only mine cars, but buckets, skips and cages, shovels, trucks, scrapers, dozers, carryalls, etc. can be built to last longer and do more work.

UNITED STATES STEEL COMPANY, PITTSBURGH · AMERICAN STEEL & WIRE DIVISION, CLEVELAND · COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
NATIONAL TUBE DIVISION, PITTSBURGH · TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. · UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
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UNITED STATES STEEL

New facts for your file on U·S·S STAINLESS

Purity Manufacturing Company makes successful switch to straight-chromium U·S·S 17 *(Type 430)* Stainless Steel

● For many years, Purity Manufacturing Company, Cattaraugus, N. Y., had specialized in fabrication of equipment from nickel-chromium grades of Stainless Steel. Because of restrictions on these grades, their attention was turned to straight-chromium Stainless Steels for many of their applications.

The firm, for more than a year now, has concentrated its production on items fabricated from U·S·S 17 (Type 430) Stainless Steel, and no special problems have been presented.

Light-gage sheets and bars are used, and the operations involve shearing, punching, roll and brake forming, arc and spot welding and grinding. Kitchen equipment for government hospitals is one of the jobs fabricated from Type 430 Stainless Steel at Purity Manufacturing Company.

Table top, drawers and racks of this hospital kitchen table are U·S·S 17 (Type 430) Stainless Steel. Table top is 10 gage, drawers are 16 x 20 gage, racks are ½" x 2".

Roll forming a portion of the rack for a hospital kitchen table at Purity Manufacturing Company, Cattaraugus, N. Y. Material used is ½" x 2" flats of U·S·S 17 (Type 430) Stainless Steel.

Type 403 Stainless Steel meets requirements for compressor blades of General Electric aircraft jet engines

USS

U·S·S STAINLESS STEEL

SHEETS · STRIP · PLATES · BARS · BILLETS · PIPE · TUBES · WIRE · SPECIAL SECTIONS

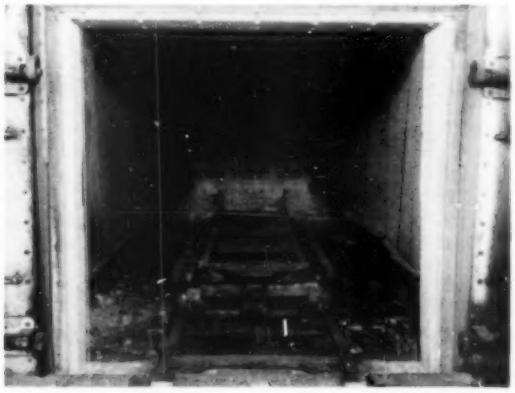
STEEL

USS STAINLESS STEEL UNITED STATES STEEL

Lead of aluminum hollows on ingot trays and dollies of Type 502 Stainless Steel ready to enter the heating furnace at Alcoa's Lafayette Works.

Straight-chromium grade of Stainless Steel solves oxidation problem at Alcoa's Lafayette Works

● Aluminum Company of America had sought a metal that would stand up under conditions encountered in their heating furnaces for homogenizing aluminum alloy ingots. Carbon steel parts and equipment had been used with relative success at temperatures for which their furnaces were originally designed. When it became necessary to substantially raise the operating temperature level, it was found that carbon steel became severely warped and oxidized in a prohibitively short time.



Interior view of the heating furnace showing the Stainless Steel lining and ceiling.

Chief operations at the Lafayette Works are remelting and casting of ingots and production of extrusions and tubing. Furnace loads range between 35,000 and 40,000 pounds, and some of the heating cycles are 18 hours, with an eight-hour period where temperatures may range as high as 1150° to 1175°F.

Three years ago, for this type of operation, they turned to U·S·S 5S (Type 502) Stainless Steel—a straight-chromium grade containing small additions of molybdenum and titanium. It is used for furnace linings and supports, baffles, ingot trays, ingot spacers, load trays and dollies.

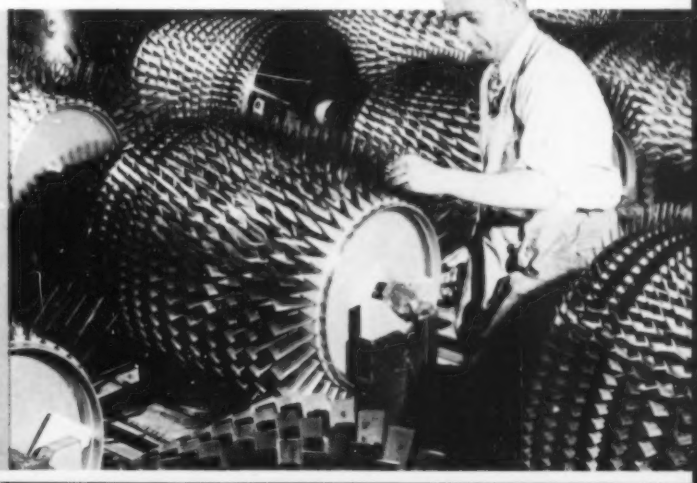
For three years now U·S·S 5S has stood up satisfactorily without failures and with a minimum of warpage and scaling. Staff Engineers are highly satisfied with the results.

Helpful facts on fabrication

Complete fabrication information on these and all the other grades of U·S·S Stainless Steel will be found in our booklet "Fabrication of U·S·S Stainless and Heat Resisting Steels." For your copy, write to United States Steel Company, 525 William Penn Place, Pittsburgh 30, Pa.

● Based on its performance in steam turbine buckets, General Electric Company has selected Type 403 Stainless Steel—another straight-chromium grade—for the compressor blades in its J47 jet engines.

The blades are forged from ⅝ in. round bar stock. Type 403 was selected for this application for several reasons, including its ability to develop high strength and its corrosion resistance properties.



Type 403 Stainless Steel is used for the compressor blades of G-E J47 jet engines.

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UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

New facts for your file on U·S·S CARILLOY STEELS

U·S·S Metallurgical Assistance saves rotary pump manufacturer $40 a ton on steel for gears

Commercial Shearing & Stamping Co., of Youngstown, Ohio, needed a good alternate steel for their rotary pump gears to replace an alloy steel that was in short supply. They called in a U·S·S Service Metallurgist for advice. After analyzing the requirements, he recommended a *less expensive* alloy steel (CARILLOY 5120).

These rotary hydraulic pumps develop pressures as high as 1500 psi. and operate at speeds up to 2,000 rpm. Gear wear must be limited to less than .005 inch to maintain high pump efficiency.

Such severe service demands a very tough, wear resistant steel. It was found in CARILLOY 5120. This steel meets every performance requirement of these precision gears, and cuts costs besides.

It cuts tool costs because it is easier to machine, and tools last longer. In addition, it requires less heat treating. Normalizing and straightening are no longer necessary, because there is much less distortion. This reduced heat-treating cost combined with a lower grade extra cuts the cost of gear steel $40 a ton—a saving of about 25%.

U·S·S Carilloy steel provides exceptionally tough, wear resistant gears at reduced cost in Commercial Shearing & Stamping Co.'s rotary hydraulic pumps. Machining is easier than before, and less heat treating is required.

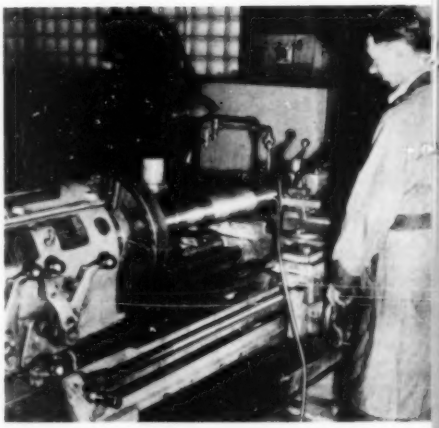
Tools last 3 times longer, production increased 14%, with U·S·S Carilloy FC steel

By changing from heat treated carbon steel to a U·S·S CARILLOY FC steel recommended by U·S·S metallurgists, Trackson Co., of Milwaukee, Wisconsin, reduced costs and speeded up production of shafts for their "PIPE LAYER."

These precision shafts must be machined to very close tolerances, and they must be strong and durable. Trackson Co. had been using 4 1/4" round bars heat treated to 269-321 Brinell. But this steel was extremely difficult to machine. Tools had to be reground and replaced frequently, and production was slow.

Trackson engineers consulted U·S·S metallurgists to find out if they could get the necessary strength and hardness from some other steel that would be easier to machine. Free-cutting, pre-hardened CARILLOY FC steel solved the problem.

This special alloy steel comes from the mill already quenched and tempered to any hardness from 255 to 375 Brinell; and it is easy to machine. As a result, tools last much longer, parts can be made faster, and the need for additional heat treating after machining is eliminated.



Drum shafts for Trackson Co.'s "PIPE LAYER" are made faster with U·S·S Carilloy FC steel than with heat treated carbon steel. Tools last much longer because Carilloy FC is easier to machine, and no heat treating is required after machining.

At Trackson Co., tools now last 3 times longer than before the switch to CARILLOY FC, and production has increased 14.3%! Trackson Co. gains these important advantages with a steel that costs only slightly more than a through hardening steel.

U·S·S metallurgists will help you with any steel problem

These case histories show how U·S·S metallurgists helped two manufacturers reduce costs and improve their manufacturing operations. In one application, they recommended a good alternate steel to use in place of an alloy steel that was in short supply; in the other, they solved a difficult machining problem.

Our metallurgists will be glad to help with any problem involving the more efficient use of steel. With wide experience and intimate knowledge of the very latest advancements in steel, they may be able to suggest a steel that is better suited to your job than the one you are now using, or perhaps they can show you how to improve your fabricating or heat-treating methods. You can contact them through the nearest U·S·S District Sales Office or by writing to United States Steel Co., 525 William Penn Place, Pittsburgh 30, Pa.

USS

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UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

STANDARDIZE YOUR LINE YET DIVERSIFY PRODUCTS

How to simplify, cut costs—and still get product versatility... with plastics

Like many manufacturers in a profits squeeze today, you may be looking for more efficient, less costly production methods—that won't sacrifice the product *flexibility* you need to meet demands of market development, and competition.

Probably the most obvious answer lies in the economical special surface treatments that are possible with molded plastic products. With plastics, you can standardize on one or two models, yet diversify them with an almost unlimited range of functional and decorative surface effects.

For instance, radio housings (or housings for small appliances, office equipment, etc.)—molded in three dimensions of versatile Lustrex styrene plastic—can be standardized in size and shape, yet gain functional and decorative variety through several colors and a few simple surface treatments.

You'll want Monsanto's new management report that explains the advantages of lacquering, printing, metallizing, hot stamping, silk screening, and other decorating techniques for plastics. Just published, this study is available to you without cost. Just use the handy coupon.

FREE—Report to Design Engineers "How to Diversify Product Lines with Special Decorative Treatments."

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Save Time,
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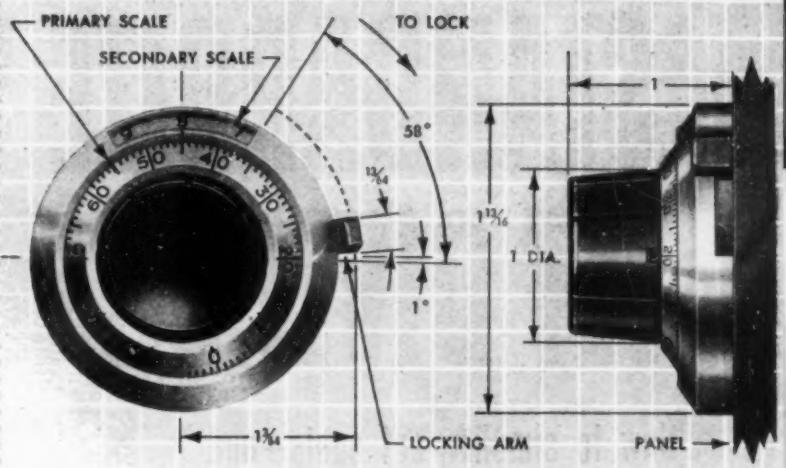
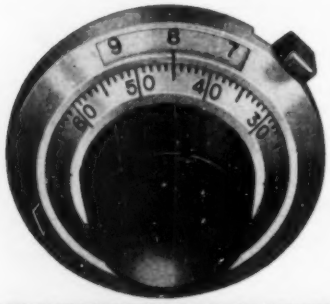
with the new multi-turn

model RA precision Duodial



Instant, accurate readings

distinctive beauty . . . quality "feel" . . . simple installation!



The new RA DUODIAL—product of the world's largest manufacturer of precision potentiometers—establishes a new standard of beauty and quality in multi-turn indicating dials. Finished in satin-chrome, with non-metallic parts of black nylon, the unit adds a distinguished appearance of quality and excellence to the finest instrument panels—and its precise operation gives a smooth "feel" that is unequalled. *From every standpoint—readability, appearance, operation, construction—here is a dial worthy of the highest quality electronic instruments!*

Unique Jump Mechanism

With its glare-proof satin finish and recessed black numerals that will not wear off, the RA DUODIAL is not only beautiful but is unusually easy to read. Moreover, the secondary dial is driven by a unique jump mechanism that keeps the dial stationary until the primary dial has completed a full revolution—then the turns-indicating dial "jumps" to the next numeral. Thus, the index always points *directly* to the number showing the particular helical turn on which the slider is positioned, eliminating errors in dial readings and settings.

Another convenience feature—three numbers show in the window at all times so that the operator knows instantly in which direction the dial is to be rotated to make the next setting. And with 10 turn potentiometers, readings are made directly in decimal equivalents of the slider position on the resistance winding—simply, accurately, and with maximum convenience for any resistance range.

Vibration-Proof Lock

All RA DUODIALS are equipped with a positive *vibration-proof* locking mechanism that can be easily and instantly set by the same hand that is adjusting the knob. Locking is accomplished by means of a cam actuated brake shoe which acts radially against an inner drum. This arrangement eliminates any possibility of dial movement during or after setting.

Easy To Mount On Panel

The RA is unusually compact—only 1-13/16" diameter (the same as a Model A HELIPOT)—and comes completely assembled, with mounting parts and hex wrench included. Installation is extremely simple. Set the dial and potentiometer at zero. Place the shaft through panel hole. Place lug plate over shaft, and mounting nut on potentiometer bushing. Then place the RA dial over shaft, lining up the register hole with lug—and tighten set screws. *It's as easy as that!*

In addition, the mounting nut is so designed that it is adaptable to thin (⅛" and under) or thick panels by simply reversing ends. No problems of adapting the unit to *your particular* panel requirements!

Finest Construction Throughout

In all respects the RA DUODIAL is built to maintain its attractive appearance and quality "feel" throughout its long life. Metal parts are machined from die-cast alloy and plated in accordance with specifications MIL P6871 and QQ P416 (1) for corrosion resistance. Non-metallic parts are made of long-lived nylon, with nylon jump gear to assure smooth quiet operation of the secondary dial. And since the primary dial is connected directly to the potentiometer shaft, no wear or backlash can affect the accuracy of the settings.

Two allen-head set screws—positioned at 90°—lock the dial to the potentiometer shaft, and the black nylon knob insulates the instrument from hand capacity.

The RA DUODIAL is primarily designed for use with the 10-turn Model A HELIPOT. However, it is equally ideal for use with the 3-turn Model C or the ultra-precision models AN and CN when these potentiometers are equipped with bushing mounting. Additional numerals provided on the secondary dial make the RA adaptable for readings up to 15 turns for special applications.

An RAJ version of the RA Precision DUODIAL is available for use on the miniature Model AJ ¾" 10-turn HELIPOT. The RAJ also fits other multi-turn devices with ⅛" shafts.

Contact your nearest HELIPOT representative for complete details—or write direct.

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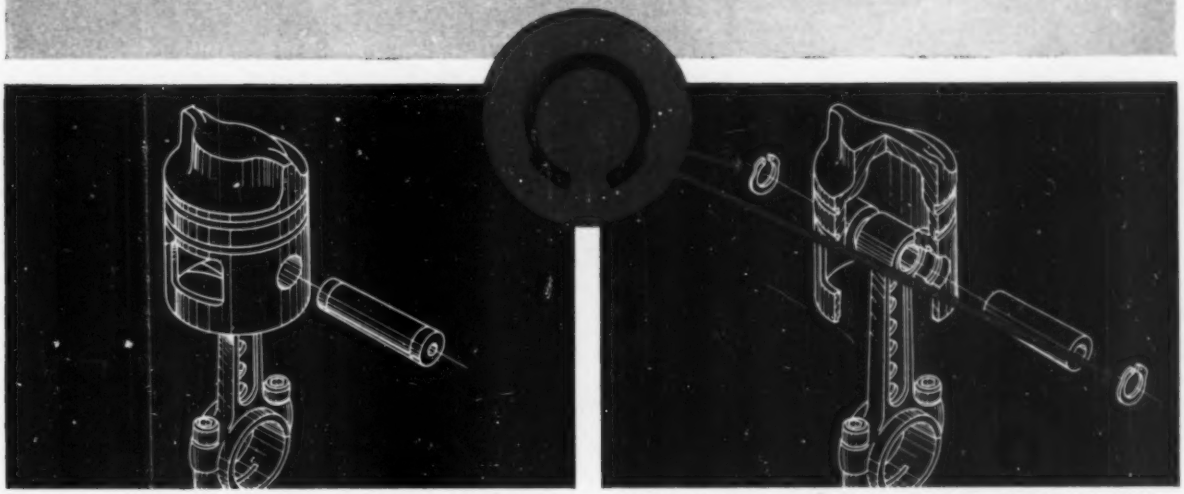
"HELIPOT" AND "DUODIAL"—T. M. REG.

2 Waldes Truarc Rings Replace 2 End Plugs ...Eliminate 3 Operations...Save $.066 Per Unit



OLD WAY Two inserted-plug type wrist pin locks hold wrist pin in place. 3 operations involved: costly machining, pressing in place, post-assembly machining. Costly maintenance problem—resulting from end plugs hammering loose.

TRUARC WAY Two Truarc Inverted Retaining Rings (Series 5008) hold wrist pin in place. Truarc Rings snap into grooves easily cut in piston, provide positive lock . . . practically eliminate maintenance costs. Quick assembly, disassembly.

Titan Chain Saws, Inc., Seattle, Washington, uses 2 Waldes Truarc Rings to replace old-style inserted-plug type wrist pin locks in their Titan chain saws. Use of Waldes Truarc Retaining Rings eliminates 2 press fit end plugs. Machining of plugs, pressing in place, finish machining—no longer required. Truarc way holds rejections to a minimum. Unit efficiency is greatly increased.

Redesign with Truarc Rings and you, too, will cut costs. Wherever you use machined shoulders, bolts, snap rings, cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better job of holding parts together.

USE OF 2 WALDES TRUARC RINGS PERMITTED THESE SAVINGS PER UNIT:

OLD WAY	
Cost of 2 end plugs Cost of pressing in and machining	$ .169
TRUARC WAY	
Cost of grooving piston Cost of 2 Truarc Rings	.103
Saving per Unit	**$ .066**

Waldes Truarc Rings are precision-engineered . . . quick and easy to assemble and disassemble. Always circular to give a never-failing grip. They can be used over and over again.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc engineers for individual attention, without obligation.

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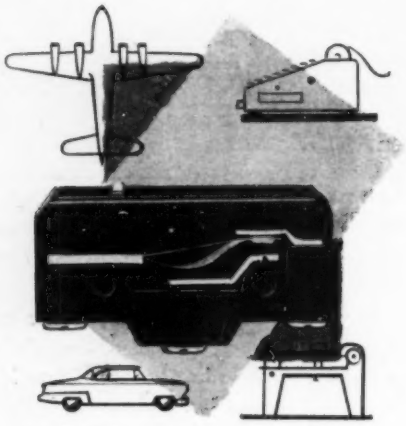
Better Products Thru Better Design

how product-design engineers, working with MICRO engineers, prove that "the use of MICRO Switches is a principle of better design".



The hardest working men today are in the great research laboratories of America.

There, spurred by dissatisfaction with present materials, machines and methods, they are working ceaselessly with chemical, electrical, electronic and mechanical forces to improve existing processes and products.

Their findings are then passed on to thousands of skilled design engineers who convert them into practical reality.

High on the list of versatile components available to these design engineers in this conversion, is the small, lightweight, highly precise MICRO switch, made in more than 6000 different combinations.

Time after time, not only in the design of new products, but in the redesign of existing products, design engineers have proved that "the use of MICRO switches is a principle of better design." Here are a few examples:

* * * *

To meet ever-increasing demands for speedier and more efficient machines in plastic-molding departments throughout industry, one molding-machine manufacturer—with MICRO engineers cooperating—completely redesigned his product, making it fully automatic through use of 14 MICRO switches! These switches make possible twelve timing, limiting and safety operations within 33 seconds—a speed never previously approached. Many progressive manufacturers have built their own molding departments around this redesigned machine. Result: faster and more accurate production at lower cost because of better design.

* * * *

In aircraft design, MICRO precision switches have proved spectacularly successful. Today, few airplanes are manufactured on the American continent that do not incorporate MICRO units in their design—from a few in small planes to over 100 in large commercial carriers and military bombers. Certain newer MICRO models (including the "subminiature," with its almost incredibly small size and weight and its outstanding performance characteristics) have brought further reductions in vital size-and-weight factors. MICRO engineers cooperate closely with the aircraft industry in anticipating the requirements of this fast-moving field.

* * * *

Among the fundamental problems of the timer industry has been the maintaining of accurate, consistent repetition of a pre-selected time interval in the timing control. Formerly, this was accomplished by cumbersome, expensive mechanisms. Today, thanks to MICRO precision switches, the process has been made simpler, more positive, less costly and less susceptible to mechanical failure. Small, high-capacity MICRO switches, with their almost everlasting repeatability of a precise operating point, have facilitated compact and streamlined design—and new efficiency—in timing controls. Further proof of what can be done when design engineers and MICRO field engineers work together.

* * * *

So it goes throughout industry—"Better Products Thru Better Design"—fresh evidence, convincing proof that "the use of MICRO switches is a principle of better design"!

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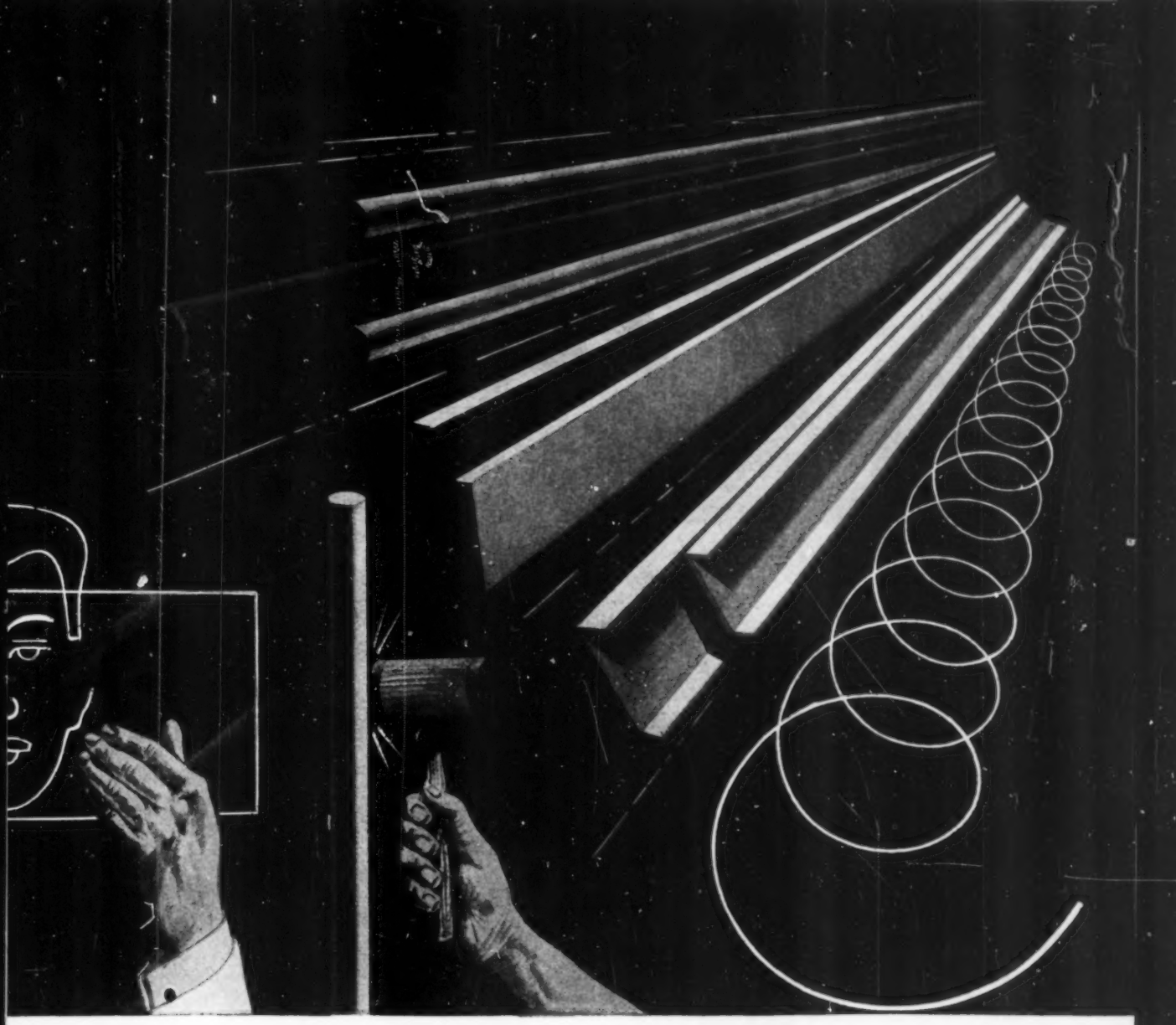

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Clarity? It's yours—with new **Marvinol NR 7045!** This outstanding new compound has *excellent* transparency. It contains no lead stabilizer, processes easily, and welds perfectly—strong as the material itself.

Whatever your specific requirements, you'll find the answer to rigids is Naugatuck. A pioneer and leader in the development of high molecular weight rigid vinyls, Naugatuck offers a series of compounds with the widest possible range of properties. Marvinol rigids have proved their ease of processing and many other advantages in years of service in chemical pipe, tubing, rods, channels, and extrusions of all kinds.

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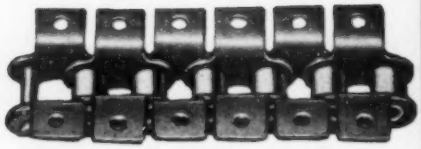
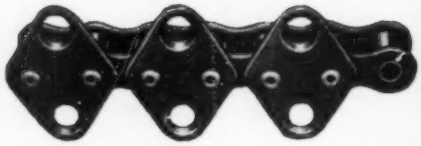
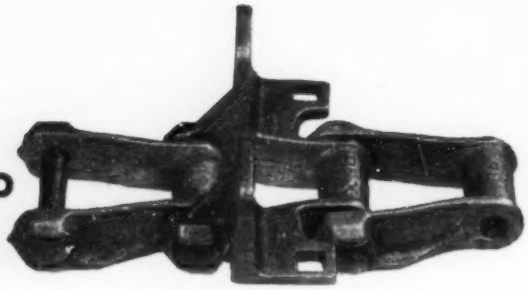
help ...help 

help ...help 

help  ...help

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In the complete CHAIN BELT COMPANY line of more than 2000 sizes and types of chain . . . *and every type has a number of attachments* . . . you'll find exactly what you need for most efficient product movement . . . greatest design flexibility. And, because the line *is* complete, you can choose the chain that will reduce costs—improve performance—insure customer satisfaction.

If exact, split-second timing is your problem, Baldwin-Rex® precision finished roller chain is your answer. If low initial cost is important, Rex® Cast Chain will meet this requirement. If heavy loads at slower speeds are your problem, a Rex Chabelco®

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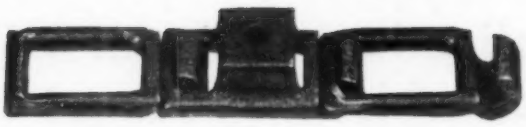

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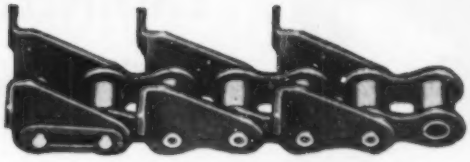

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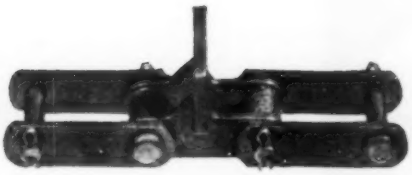

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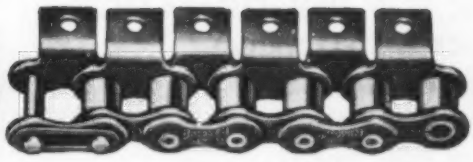

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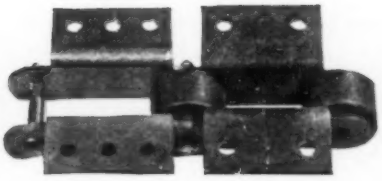

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STEP 1

ENGINEER THE PERFORMANCE OF YOUR a Century application engineer will from this wide range of

FOR TOP PERFORMANCE SELECT THE ELECTRICAL CHARACTERISTICS TO MATCH THE LOAD FUNCTIONS OF YOUR EQUIPMENT

- ☐ SINGLE PHASE OR POLYPHASE A.C. OR D.C.
- ☐ SELECTION OF RATING FROM WIDE RANGE —⅛ to 400 H.P.
- ☐ SELECTION OF PROPER LOADING FACTOR FOR SAFE TEMPERATURES AND EFFICIENT OPERATION:
  - ☐ Continuous general purpose rating.
  - ☐ Short time special rating.
  - ☐ With consideration to ambient temperatures for either of these.

SELECTION OF VARIOUS TORQUE CHARACTERISTICS FOR:

- ☐ Starting torque required which varies with class of equipment.
- ☐ Accelerating torque required which varies with inertia—friction—compression of the load.
- ☐ Maximum torque required which may vary with momentary overloads.

SELECTION OF TORQUE CHARACTERISTICS AND RATING FOR REVERSING ROTATION OF LOAD:

- ☐ Where motor comes to full stop before reversing.
- ☐ For instantaneous reversing (plugging) with reference to load inertia or other load factors.

SELECTION OF RATING FOR "START" AND "STOP" CYCLE FOR:

- ☐ Standard ratings for infrequent starts and stops.
- ☐ Special rating depending on frequency of starts and stops.

SPEED REGULATION AND CONTROL FOR:

- ☐ Select normal slip for good constant speed regulation.
- ☐ Select high slip, to absorb shock of impact loads.
- ☐ Select adjustable varying speed for uniformly constant load.
- ☐ For speed adjustment in fine steps, variable load, use adjustable voltage control.
- ☐ For speed adjustment in wide fixed steps, use multi-speed motors furnished for:
  - ☐ Constant H.P.
  - ☐ Constant torque
  - ☐ Variable torque

SELECT MOTOR WITH:

- ☐ Normal starting current for power circuits with good voltage regulation.
- ☐ Lowest starting current for power circuits where voltage fluctuates widely (R.E.A. lines).

STEP 2

PROTECT THE VITAL PARTS OF THE MOTOR FROM VARIOUS ATMOSPHERIC HAZARDS — SELECT THE MOTOR FRAME PROTECTION

☐ **DRIP PROOF — OPEN TYPE GENERAL PURPOSE FRAME**

For normal atmospheric conditions.

☐ **SPLASH PROOF — OPEN TYPE FRAMES**

Can be used out of doors without further protection or in plants where equipment must be washed down with a hose. For plants like dairies or other processing plants. Or for cooling towers, oil field pumping units, etc., out of doors.

☐ **DUST PROOF — TOTALLY ENCLOSED FAN COOLED FRAME**

The vital parts of the motor are sealed in. Used where the atmosphere is charged with abnormal amounts of dust, grit, oil fog, etc. This frame has high acceptance in high speed mass production metalworking plants or wherever a highly charged atmosphere would affect the life of the motor.

☐ **EXPLOSION PROOF — TOTALLY ENCLOSED FAN COOLED FRAME**

The frame is sealed in, in a manner which prevents a spark inside the frame from igniting combustible materials or gases outside the frame. The motors have an "Underwriters' Label" indicating the design has been approved by the Underwriters' Laboratories for certain specified classes of explosives.

☐ **TEXTILE — OPEN TYPE FRAME**

This motor is designed with wide open air passages, with smooth surfaces. It actually sheds lint, with which the air is highly charged in textile plants.

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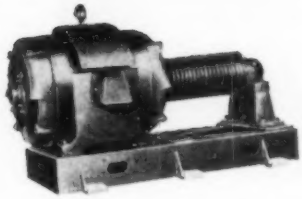
Century motors have been satisfying the requirements of equipment manufacturers — often with the most exacting specifications. This has produced a great teamwork between Century engineers and the customers' engineering department.

"Century OFFERS hundreds of mechanical forms for best adaptation to your equipment. ASK FOR IT— WE HAVE IT!"

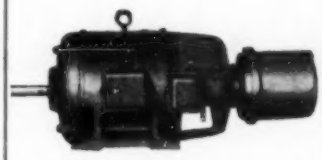
STEP 3

FOR IDEAL ADAPTATION OF THE MOTOR TO YOUR EQUIPMENT—

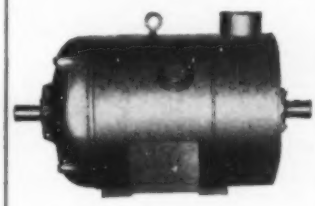
Here are a few samples of the many mechanical forms to select from



☐ **1.** 200 H.P. Squirrel Cage Motor. 3 bearing construction with pulley for V-belts.

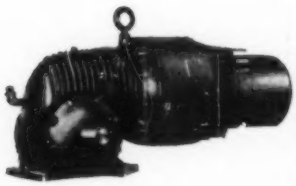


☐ **2.** 25 H.P. Slip Ring Motor with brake.

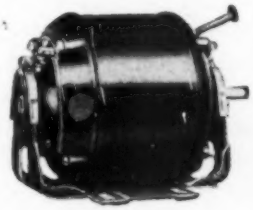


☐ **3.** 40 H.P. Slip Ring Motor — double end shaft — with air connection for forced cooling.

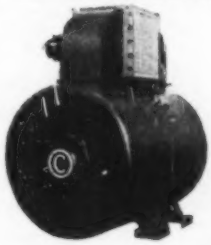
☐ **4.** Pump Motor with standard NEMA Type "P" face bracket for vertical or horizontal mounting.



☐ **5.** 3 H.P. Right Angle Gear Motor with brake.



☐ **6.** Cushion Base Motor with extended oilers for use on furnace blowers.



☐ **7.** 30 H.P. Direct Current Totally Enclosed Unit Cooled Motor.

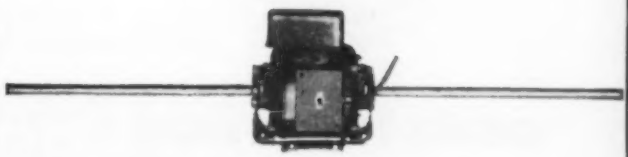
☐ **8.** Vertical Unit Heater Motor supplied with cushion rings and extended through bolts.

Ask about a sample

Century motor, scientifically selected, for actual test performance on your equipment.

Ask about Century's National Network of Authorized Motor Service Stations to solve your motor service problems in the field.

☐ **9.** Jet Pump Motor with NEMA Type "C" face type bracket — with threaded shaft.



☐ **10.** Special Double End Shaft Motor with switch and cord used to drive multiple blowers on air circulating unit.

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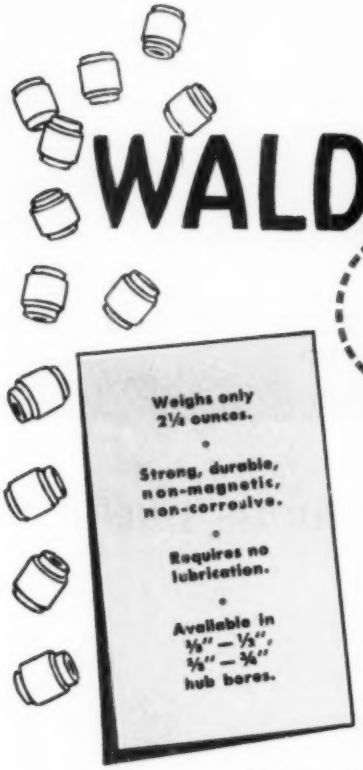
WALDRON *Junior* GEAR COUPLING

Patent applied for



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This amazing new WALDRON Junior Gear Type Coupling has two externally geared hubs enclosed in an internally geared sleeve that takes any size hub from ⅛" to ¾" bore. Made of smooth, tough, unbreakable nylon, it withstands corrosion and is not affected by most liquids and gases.

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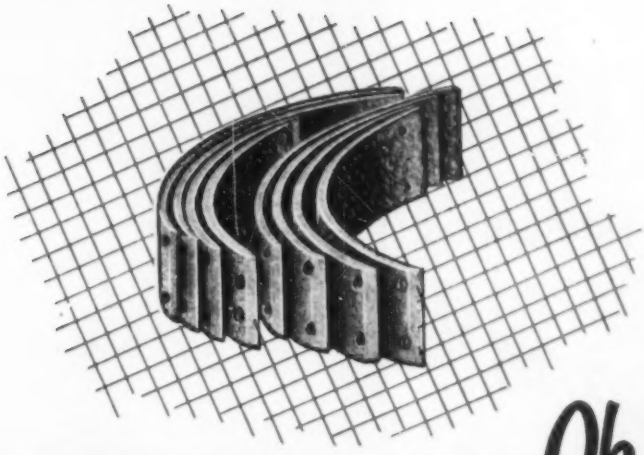

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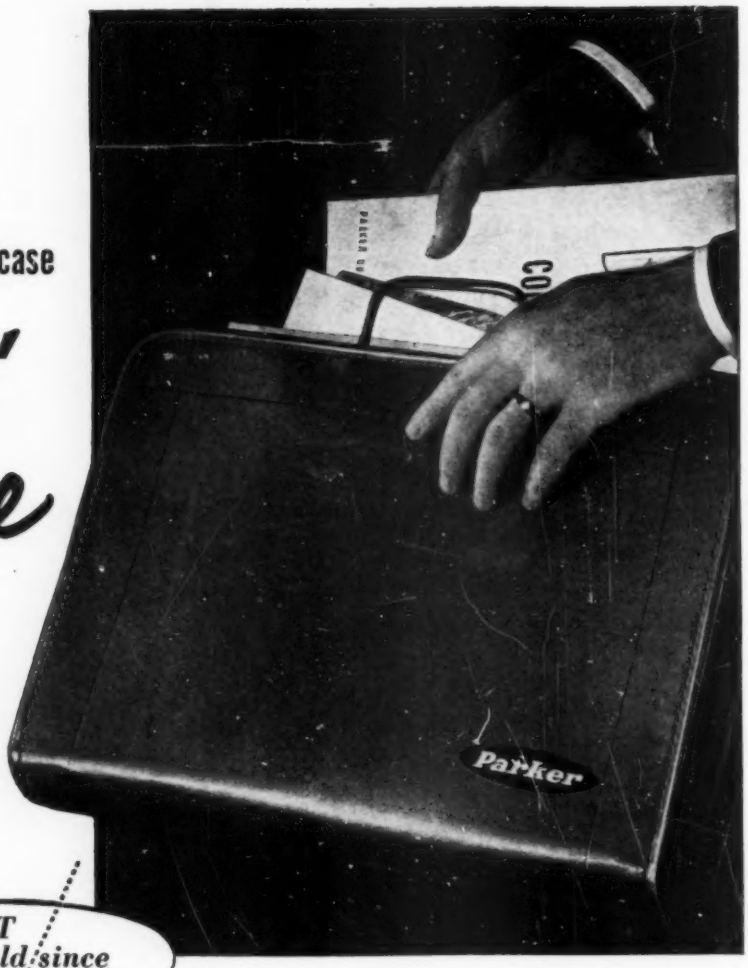
38 Years' Experience

in metal surface treatment to you



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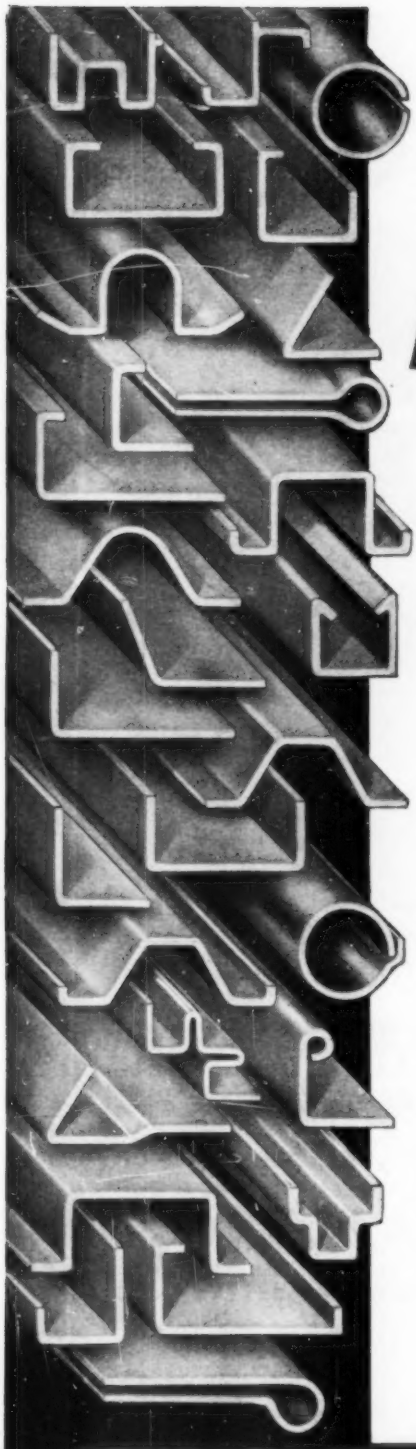

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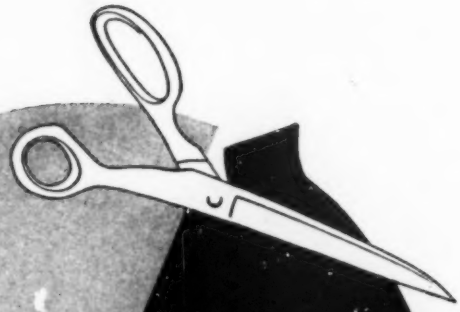
products change

...but this job never changes



assembly costs

component costs

trim assembly's "bite" in production costs with...

Assembly's percentage of total production costs runs from less than 10% in simple "gadgets" to as much as 75% in modern aircraft. Trimming this percentage to the lowest figure possible is a continuing challenge to everyone concerned with design, procurement, and production.

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Here's a new, modified Polystyrene for large moldings

KOPPERS MC 405 is used for the interior panels of both doors, the freezer compartment and for door shelves in this latest Admiral Dual-Temp Refrigerator. These are excellent examples of the large, accurate moldings which can be formed quickly and easily with this new modified polystyrene.

Each of the sections mentioned above was injection-molded in a single operation, and the speed and ease of molding resulted in a far lower unit cost than would have been possible with conventional construction methods and materials. The light weight of the sections effected substantial savings in freight and storage costs. The MC 405 moldings combine good resistance to shock and impact, dimensional stability, a smooth, attractive finish and low heat conductivity.

The characteristics of Koppers MC 405 suggest it as the ideal construction material for trays, cabinets, strips and other refrigerator parts as well as for housewares, battery cases, toys, containers and displays.

Write today for further information about MC 405 and Koppers other Modified Polystyrenes. If you desire, a Koppers representative will gladly call to discuss the suitability of any of Koppers Polystyrenes for your particular product applications.

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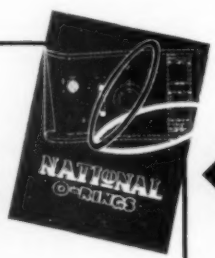
The most broadly useful compilation of O-Ring data. Includes engineering, design and compound information, gland-groove and back-up ring requirements, etc. Lists all National O-Rings. Please request free copy on your Company letterhead, giving your title.



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BRIDGEPORT BRASS COMPANY

COPPER ALLOY BULLETIN

"Bridgeport" MILLS IN BRIDGEPORT, CONN. AND INDIANAPOLIS, IND.—IN CANADA: NORANDA COPPER AND BRASS LIMITED, MONTREAL

Three stages in the manufacture of an electric light reflector from brass by the spinning process. Courtesy Lehrolite Inc., Wallingford, Connecticut.

Spinning Brass and Copper

Spinning is a method for making hollow shapes from sheet metal discs by pressing a tool against the rotating metal which is backed up by a spinning chuck of the desired shape. It is economical for small production lots only, because the initial outlay for tools and equipment is small.

However, this fairly ancient process is still used for the manufacture of "hand-made" items in limited quantities such as electric lighting fixtures and table lamps; vases, gift items, parts for candlesticks, frying pans, pots, special parts for electronic devices, etc.

Variety of Metals

Spinning is not limited as to size of the part or kind of metal. All wrought metals can be spun provided adequate power is available to exert sufficient pressure to make the metal flow to the desired shape.

To attain a deep or intricate shape, spinning is done in stages using different shaped chucks for each operation.

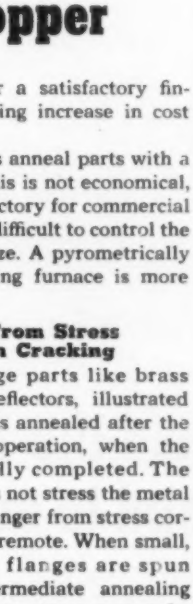
Grain Size Important

For a smooth finish, the annealed brass sheet should generally have a medium fine grain size, say .040 to .050 millimeter on metal between .020 to .045" in thickness. On heavier gauges, a larger grain size may be required for easier spinning. However, since most jobs call for annealing or softening at intermediate stages, which is necessarily performed by the fabricator, he should take care not to over-anneal the metal so as to produce a coarse grain structure. After spinning this may result in a rough, grainy (orange peel) surface which requires unnecessarily long polishing for a satisfactory finish. A corresponding increase in cost follows.

Many operators anneal parts with a gas-fired torch. This is not economical, uniform, or satisfactory for commercial runs because it is difficult to control the anneal or grain size. A pyrometrically controlled annealing furnace is more desirable.

Danger From Stress Corrosion Cracking

In making large parts like brass lighting fixture reflectors, illustrated above, the metal is annealed after the second spinning operation, when the shape is practically completed. The final spinning does not stress the metal excessively and danger from stress corrosion cracking is remote. When small, deep parts like flanges are spun without any intermediate annealing operation, excessive stresses may be developed. This may lead to stress corrosion cracking provided other conditions also exist such as the presence of moist ammonia, even in traces so slight that it cannot be detected by the sense of smell; air or oxygen; and the element of time. This combination of conditions may easily take place outdoors, or when poor conditions of storage generate ammonia from decomposed products containing nitrogen. Residues from cyanide cleaning solutions on the metal surface and dampness may decompose to form ammonia.

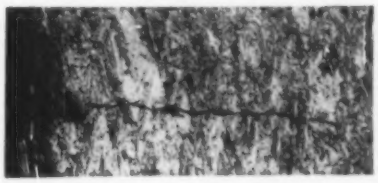


Decorative pierced metal lighting fixture made from brass or copper. Courtesy Lehrolite Inc., Wallingford Connecticut.

70-30 brass annealed. .045 mm. Grain size. Mag. 75x

Preventing Stress Corrosion Cracking

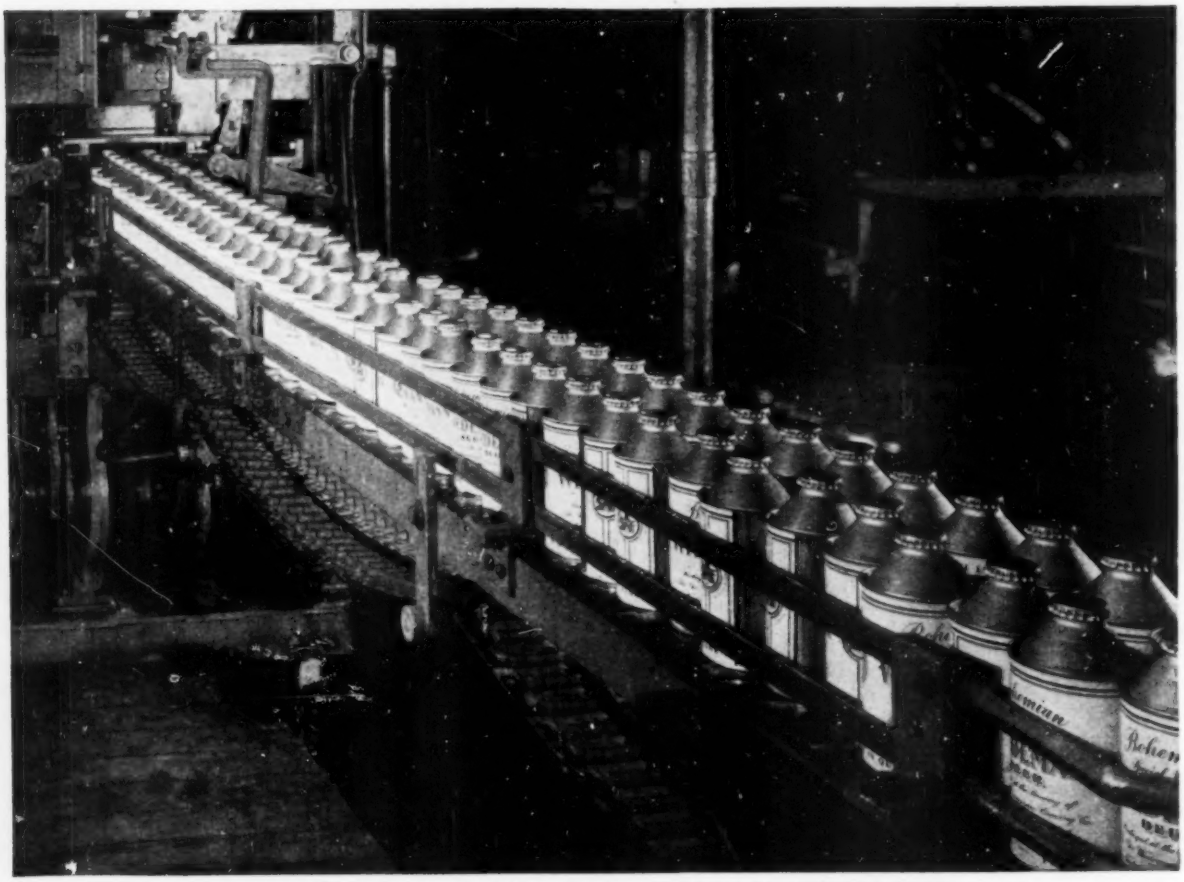
Stress corrosion cracking can be prevented by relieving excessive stresses by heat treatment. A special type of furnace is required where the gases are



blown on the work and the heat is transferred by conduction rather than by radiation. Heat treatment at a temperature between 520°F to 575°F for about a half hour or longer, depending upon the load, will relieve stresses with no appreciable softening of the brass.

Copper and high-copper brasses, silicon bronze, and cupro nickel are considerably less susceptible to stress corrosion than yellow brass and generally do not require stress relief heat treatment. Our Metallurgical Laboratory will be glad to help customers that are experiencing trouble from stress corrosion cracking or other metal problems encountered in the fabrication of metal goods. Write for Bridgeport Brass "Technical Handbook" (168 pages) on company stationery. (9066)

no ONE chain serves every purpose



S-815 flat top chain carrying cans of beer at The George Wiedemann Brewing Company, Newport, Ky. This sturdy, economical medium is easily kept clean and assures a smooth ride for such products.

LINK-BELT offers the RIGHT chain for every job . . . engineered to meet your requirements

Typical conveyor chains from the complete Link-Belt line

Class RC crescent flat top chain—travels in horizontal planes, around corners; ideal for bottles and cans.

Class 400 swivel chain — carries cartons, cases, etc. over paths with both vertical and horizontal turns.

Class RC flat top chain — precision made for smoothest, spill-free carrying and long life.

Class RC universal crescent flat top chain can be used for multiplane operation traveling variety of paths.

Link-Belt offers no single "cure-all" chain to handle every job. From the most complete line of chains and sprockets—we can recommend the best type to fit your particular requirements—cast, combination, forged and fabricated steel, roller or silent. So, whatever your chain problems, large or small, Link-Belt engineers will work with you or your consultants to help solve them.

LINK-BELT COMPANY: Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa). Offices, Factory Branch Stores and Distributors in principal cities.

12,513-C

LINK-BELT

CHAINS AND SPROCKETS

LOGAN FLUID POWER • DURABLE, DEPENDABLE SINCE 1916

Victoria Falls on the Zamloza River, Rhodesia, Africa. Width of falls, 1860 feet. Spills into narrow chasm between sheer walls 400 feet high. Volume, 62 million to 100 million gallons per minute.

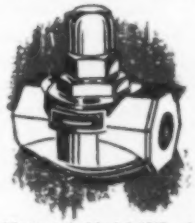
Illustrated, Model 4015—4-way, 2-position valve for directing pressure alternately to ends of double-acting hydraulic cylinder.

LOGAN HYDRAULIC CONTROL VALVES

A broad range of types and sizes to most effectively meet any requirement—Design Engineers, Machine Operators, Maintenance Men appreciate these Logan advantages

- LONG-LIFE CONSTRUCTION
- EASY TO SERVICE
- INFREQUENT MAINTENANCE
- EASE OF INSTALLATION
- EFFORTLESS OPERATION
- UNRESTRICTED PORTING

Let Logan Engineers help you design your Air and Hydraulic Circuits



Illustrated, Model 8015 adjustable speed control valve. Install between operating valve and one end of cylinder to meter flow of oil in one direction with free flow on return.

LOGAN MANUFACTURES 6,975 STANDARD CATALOGED ITEMS

FREE CATALOG ON REQUEST

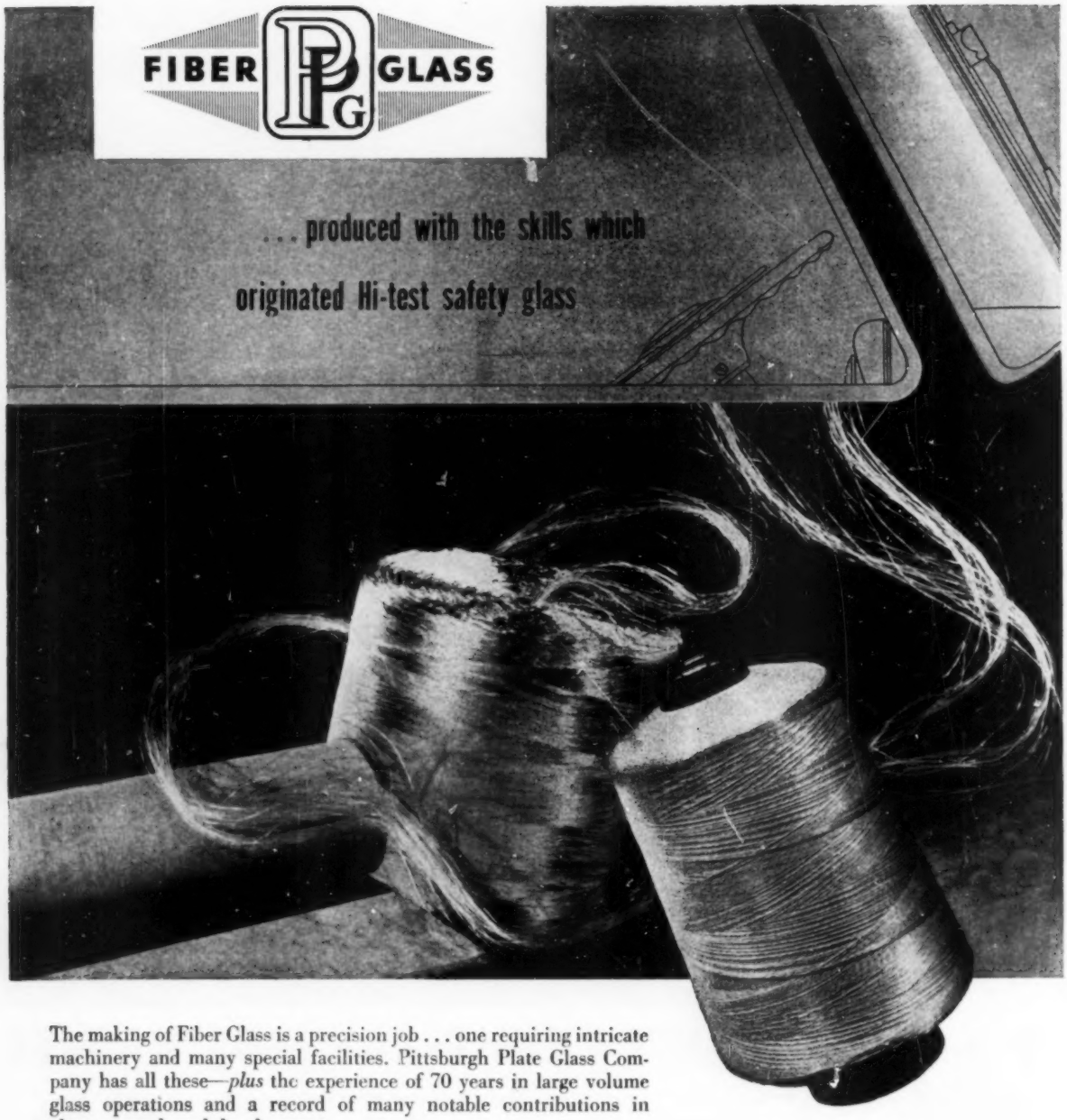
AIR CONTROL VALVES, Cat. 100-4 • AIR CHUCKS, Cat. 70-1 • AIR CYLINDERS, Cat. 100-1 • AIR-DRAULIC CYLINDERS, Cat. 100-3
AIR and HYDRAULIC PRESSES, Cat. 51 • COLLET GRIP TUBE FITTINGS, Cat. 200-5 • HYDRAULIC CONTROL VALVES, Cat. 200-4
HYDRAULIC CYLINDERS, Cats. 200-2; 200-3 • HYDRAULIC POWER UNITS, Cat. 200-1 • SURE-FLOW COOLANT PUMPS, Cat. 62

SAVES TIME — Logan — AIR AND HYDRAULIC EQUIPMENT — EFFORT • MOTION

LOGANSPORT MACHINE CO., INC., 812 CENTER AVE., LOGANSPORT, IND.

FIBER PPG GLASS

. . . produced with the skills which originated Hi-test safety glass



The making of Fiber Glass is a precision job . . . one requiring intricate machinery and many special facilities. Pittsburgh Plate Glass Company has all these—*plus* the experience of 70 years in large volume glass operations and a record of many notable contributions in glass research and development.

Today, for example, Pittsburgh's Hi-Test Safety Glass is the standard in many automobiles—the result of exhaustive research which originated the lamination of glass with an interlayer of vinyl plastic and devised methods which made volume production practicable.

Now these skills are backing up the production of Fiber Glass, assuring both excellence of product and the efficient handling of users' requirements. If Fiber Glass is used in your products—either Superfine Insulation or Yarns, Strands or Roving—investigate the advantages which can be obtained by specifying "*Pittsburgh*"—PPG Fiber Glass. Pittsburgh Plate Glass Company, Fiber Glass Division, 632 Duquesne Way, Pittsburgh 22, Pa.

engineering service available

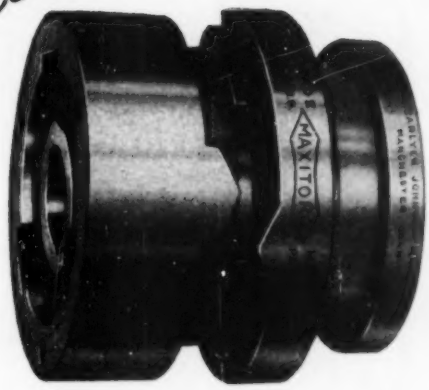
Opportunities for improving products or production methods involving the use of PPG Fiber Glass are so great that our field engineers may be able to contribute information of value to you. Arrangements for this service, or for obtaining data on PPG Fiber Glass, may be made through our executive offices in Pittsburgh, or our district sales offices in Detroit, New York, Cleveland, Chicago, Cincinnati and Washington.

FIBER PPG GLASS PAINTS • GLASS • CHEMICALS • BRUSHES • PLASTICS

PITTSBURGH PLATE GLASS COMPANY

MAXITORQ *automatic*

OVERLOAD RELEASE



CLUTCH

To designers and manufacturers of high-speed automatic machinery, Carlyle Johnson offers practical engineering recommendations for applications of this protective power transmission unit.

Let's consider, for instance, a can or bottle labeling machine . . . when an accidental overload shock occurs. Labels go flying all over the place, cans or bottles gang up and are dented or broken, the driving mechanism is jammed . . . and all that costs money and down-time.

But not if your original power transmission is controlled by the Maxitorq automatic Overload Release Clutch, which is manually adjusted to transmit the normal running load and instantly disengages into neutral when the overload strikes. With a minimum of clean-up, the clutch is re-engaged . . . and all is well.

Overload Release Cups (note the cam construction) are the means by which the clutch is connected to the driven or driving member. We make them at relatively low cost . . . and can also supply hub, ring, flange, or cut-off coupling types to suit your specific conditions. Clutches standardized in 6 sizes, ¼ to 5 H.P. @ 100 r.p.m.; working torque, 13 to 263 ft. lbs.

Send for bulletin #150—PE-1

THE CARLYLE JOHNSON MACHINE CO.

MANCHESTER . . . . . CONNECTICUT

3CJ53

Frankly

SPEAKING

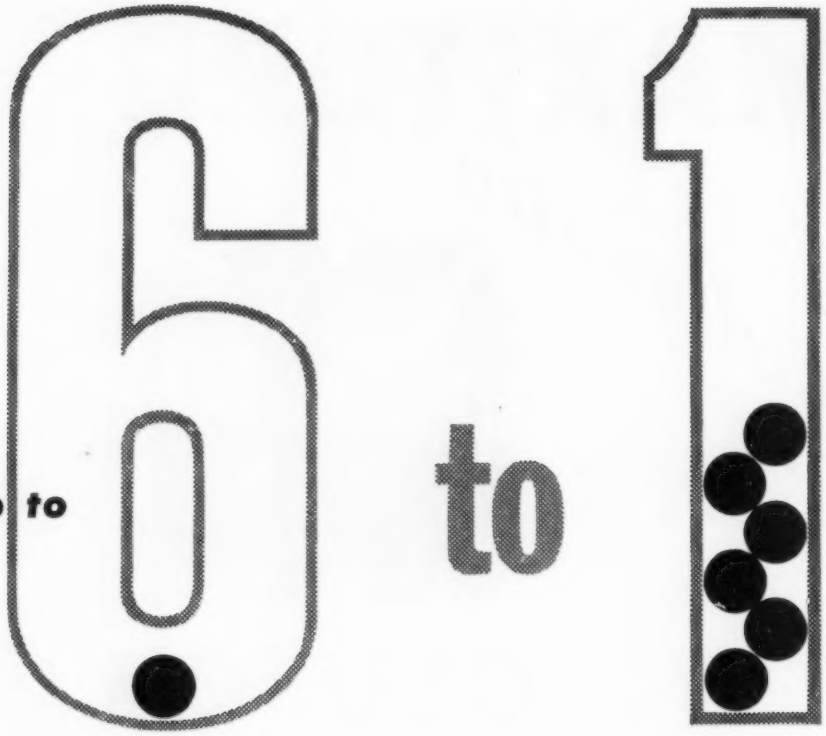
There are quite a few types of clutches but, within its capacity, the Maxitorq Floating Disc Clutch is not excelled in applications for which it is intended. The Carlyle Johnson Machine Company is celebrating its 50th anniversary of clutch manufacture. Throughout those years, our engineers have developed new design features, more and more compact construction, improved wearing qualities, and better machining practices for maintaining reasonable costs.

Perhaps the outstanding design feature is the patented "Separator Springs," a definite improvement that moved multiple disc clutches up to the front line. Used between each pair of inner discs, they spread them endways with an accordion action, so that light may be seen between all discs when the clutch is in neutral. Therefore, there is no drag, no abrasion, no heating. The discs actually "float" or ride free when the clutch is in the neutral position.

Carlyle Johnson's method of finishing the engaging faces of the discs assures flat, true surfaces. This means that under engagement there are no high or low spots . . . the entire area of the surfaces has an evenly distributed contact. Obviously, disc service life is greatly extended. Such refinements are the result of continuous study by our engineers to make and keep the Maxitorq name high on the list of machine and product designers for their original equipment for control of power transmission.

Your problems are in good hands if you put them up to our engineers for solution. We've traveled the country over to check on the best and most practical installations . . . and we're on call whenever a problem arises. Just ask for Frank R. Simon, The Carlyle Johnson Machine Company, Manchester, Conn.

When SCHATZ can save you up to 6 to 1



Why pay for unneeded precision in ball bearings?

In many applications where speeds and loads are moderate, you don't need a precision bearing. When this is the case, Schatz "Commercial" Ball Bearings can cut your costs by as much as 85%—*without any sacrifice in operating efficiency.*

Why are savings like this possible? Because "Commercial" Ball Bearings are designed to wider tolerances than precision bearings...because they are available unground, partially-ground, or fully-ground. And, because, in almost all cases, cages are not used.

If you have an application where speeds and loads are moderate, it will pay you to look into Schatz "Commercial" Ball Bearings. To learn how you may save, write for literature described below.

THE SCHATZ MANUFACTURING COMPANY
6758 Fairview Avenue, Poughkeepsie, New York

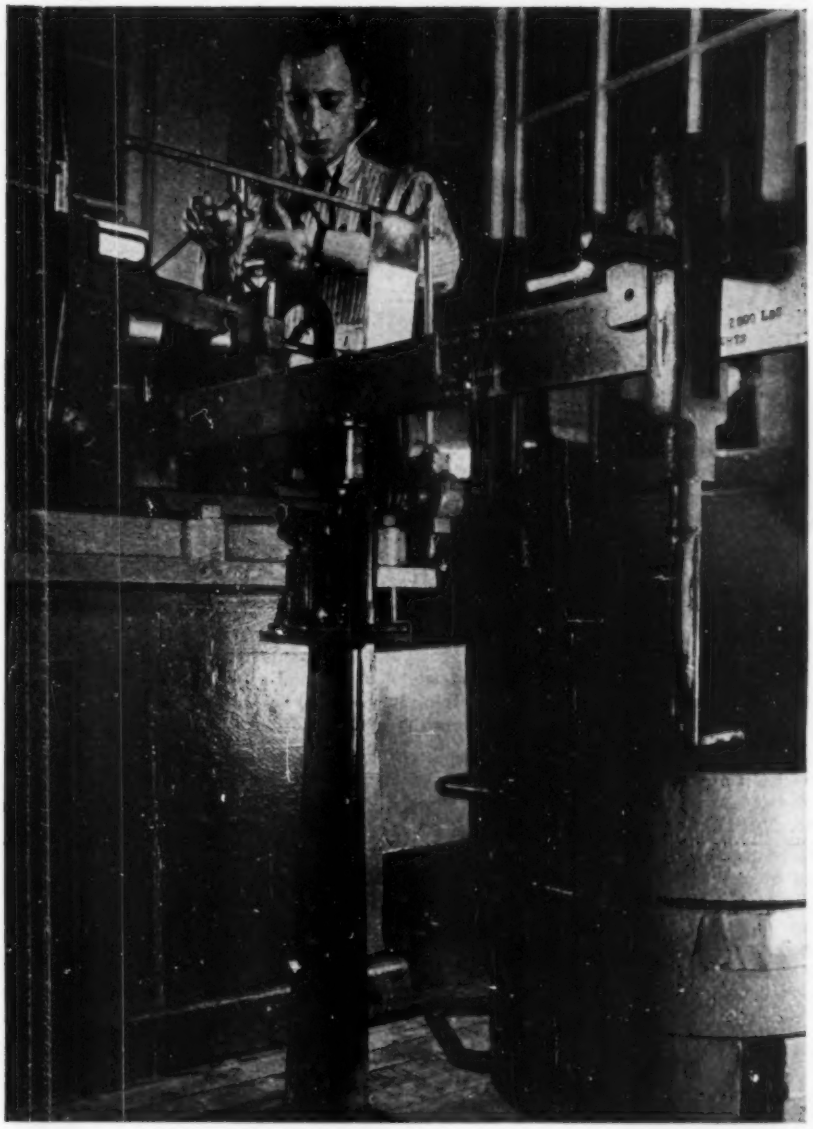
Schatz "Commercial" Bearings used on these products

Dishwashers • Outboard motors
Automobile steering mechanisms
Elevators • Box machinery
Office equipment
Flexible shafts • Lawn mowers
Masonry cutting equipment
Textile machinery • Farm equipment
Laundry equipment
What about your product?

The oldest, largest manufacturer of "Commercial" ball bearings

SCHATZ "Commercial" BALL BEARINGS

Technical literature available:
Schatz Catalog 11 contains drawings and specifications of Schatz Ball Bearings.
Technical Bulletin tells how to determine proper type and size "Commercial" Ball Bearing for various speeds and loads.
Nylon Bearing Parts discusses advantages of nylon parts in "Commercial" bearings.



Failure is his business

and it makes ours a success

When we design a new ball bearing at Federal, one of our project engineers works out its estimated life under the specified speeds and loads. But this is on paper only, and that's not proof enough.

So the next step is to have a prototype bearing constructed by hand. It is placed in a machine like the one above, put under load, and run until it fails. These prototype bearings are made again and again and tested in this way until we are satisfied with the findings.

But, when the tests are finished, we *know* exactly what a bearing will do. That's why you can be *sure* of top performance from every Federal Ball Bearing.

The Federal Bearings Co., Inc., Poughkeepsie, N. Y.

Federal
Ball Bearings

One of America's Leading Ball Bearing Manufacturers

DIE CASTING
means strong lightweight assemblies at minimum cost

2000 impacts per minute. Does the work of hand wrenches; drills and taps.

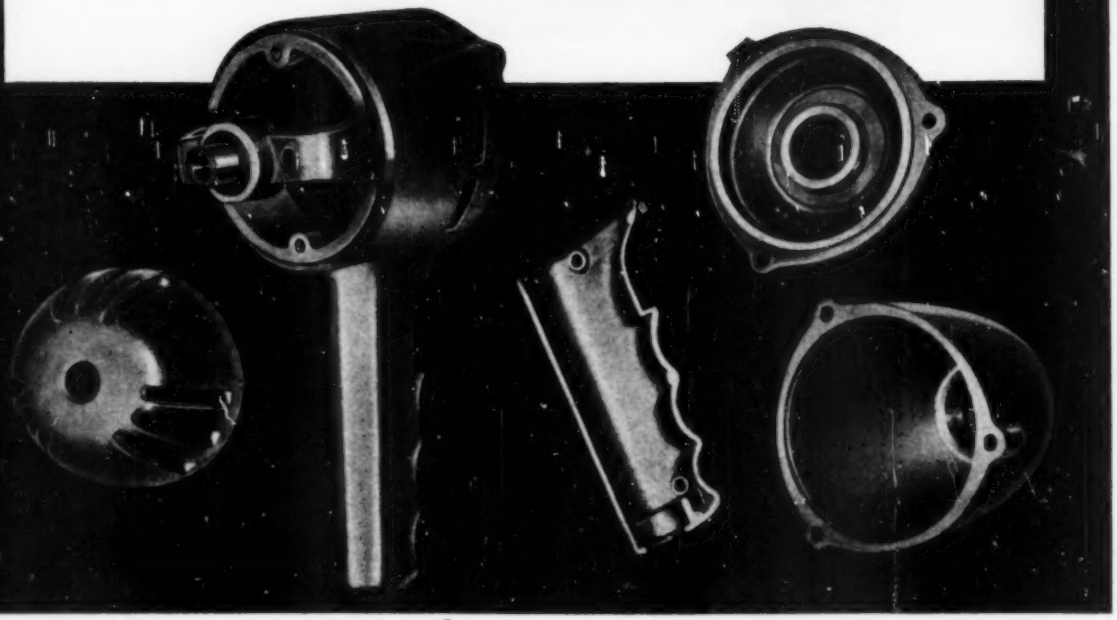
CASE HISTORIES FROM MT. VERNON FILES

If you use metal parts in appreciable quantities, die casting merits your careful consideration. For die casting not only simplifies and speeds production, but assures strong, lightweight, quality products at *minimum* cost.

These outstanding advantages are gained by the experienced Millers Falls Company, makers of tools since 1868, who specify die casting for the housing of their No. 555 Impact Tool.

The four parts of this housing, plus trigger and hand-grip, are produced quickly and economically by Mount Vernon. Cast from aluminum, complete with bronze bushings and other structural details as specified, these parts fit accurately together with minimum machining. Result: A lightweight, strong, good looking assembly *produced inexpensively.*

When next you have to decide upon a manufacturing procedure, focus on Mount Vernon die casting — and send us your specifications. We'll be glad to put our wealth of experience at your disposal, and show you the way to lower unit costs, increased output, improved products.

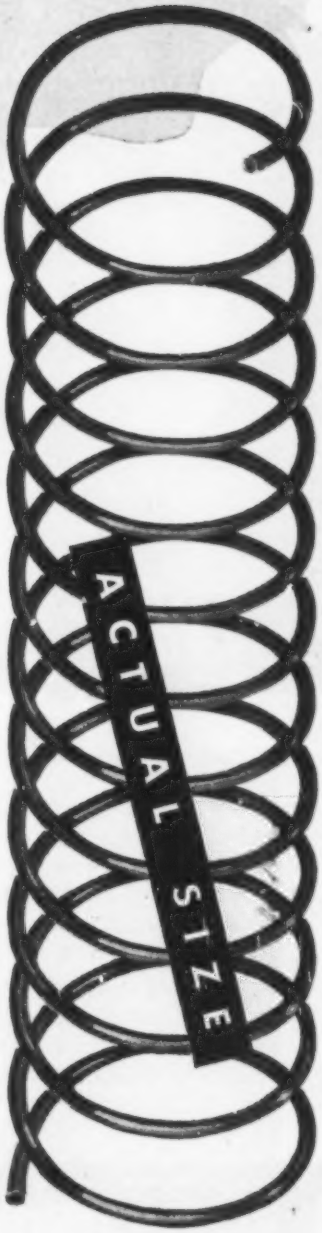


Engineers, like you, prefer

CAPILATOR*

... the Wolverine capillary tube used for restriction purposes

because it is PLUG DRAWN



Through the special Wolverine process of plug-drawing this tiny tube a smooth, glass-like finish is imparted to the inside wall. This exceptionally fine surface assures a uniform and uninterrupted flow of liquids and gases through the tube.

The Capilator is one of Wolverine's products developed to render controls more dependable and bring higher operating efficiency to the products you manufacture.

WOLVERINE TUBE DIVISION

of Calumet & Hecla, Inc.

Manufacturers of tubing exclusively

1415 Central Ave. Detroit 9, Mich.

*REG. U. S. PAT. OFF.

PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA

Sales Offices in Principal Cities

Export Department, 13 E. 40th St., New York 16, N. Y.

Machine tool idea pool

In designing machine tools, as in planning countless other products, OSTUCO Steel Tubing provides an endless pool of practical ideas because of its *unlimited adaptability*. Collets, chucks, spacers, spindles, bearings, shafts, ferrules, and handles are but a few of the applications.

By varying the radius of a bend, the length of a taper, the dimension of an upset, etc., an old design can be improved or a new one created. By combining such operations, a part can be made to serve several functions, thus simplifying design. Parts may even be fabricated or forged beyond recognition as a tube section.

Whether you design machine tools or products of a distinctly different nature, you will want to investigate the many quality-improving, cost-reducing features of OSTUCO Tubing.

Write Dept. PE-1 for "OSTUCO TUBING"—a new, informative catalog on seamless and welded tubing and its fabricating.

From Your Blueprint . . . to Your Product
OSTUCO TUBING
Tapering • Swaging • Flanging • Bending
Upsetting • Expanding • Reducing • Beading
End closing • Spinning • Drilling • Slotting
Notching • Flattening • Shaping • Trimming
Threading • Angle Cutting • And Many Others

THE OHIO SEAMLESS TUBE COMPANY
Manufacturers and Fabricators of Seamless and Electric Welded Steel Tubing
Plant and General Offices: SHELBY, OHIO

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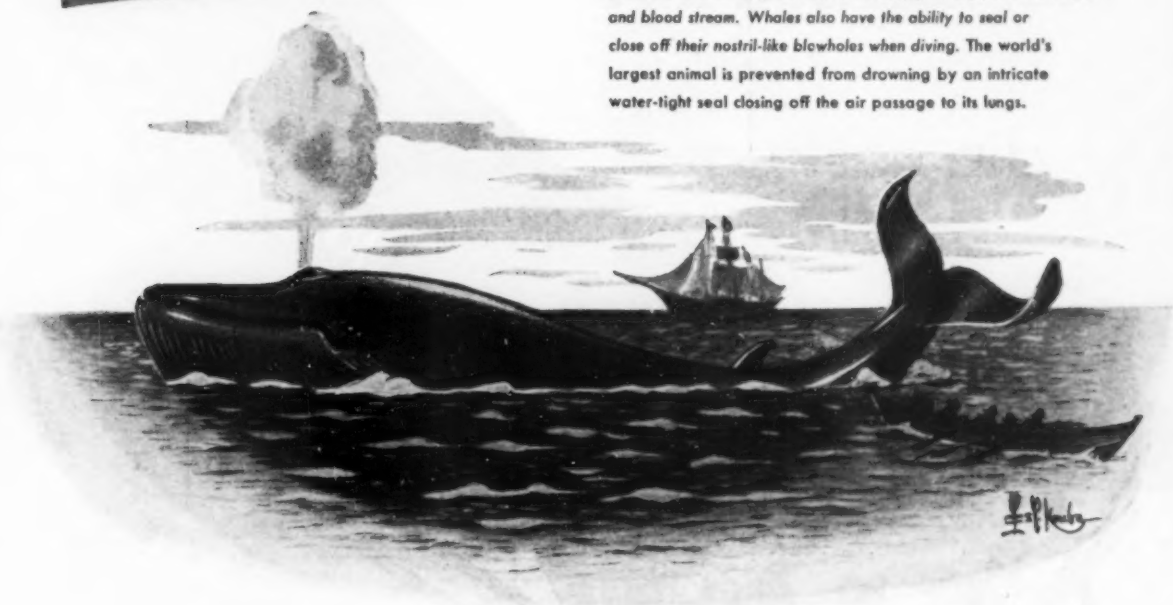
LESSONS IN HYDRAULICS

The Great Whale

* *Whales are the largest animals the world has ever known—larger even than dinosaurs. Blue or Sulphur-bottom whales may reach 75 or 100 ft. in length and weigh as much as 125 tons. While they look like fish and live only in the oceans, they are warm blooded, have lungs and breathe air. They are not fish but true mammals. The whale has phenomenal ability to "hold its breath" (up to an hour) while submerged. This is possible because its heartbeat and body movements slow down under water making good use of the supply of oxygen in its lungs and blood stream. Whales also have the ability to seal or close off their nostril-like blowholes when diving.* The world's largest animal is prevented from drowning by an intricate water-tight seal closing off the air passage to its lungs.



NATURE'S WATER-TIGHT VALVE

The dependability and wide application of Minnesota O-Rings prove themselves in such equipment as gas valves . . . hydraulic brakes . . . compressed air equipment . . . steam or gas engines . . . lubricators . . . refrigeration machinery . . . spraying equipment. Made from special compounds of natural or synthetic rubber to satisfy specific requirements and meet rigid quality standards, *Minnesota O-Rings are the obvious answer for better packing installations in air, gas or hydraulic systems.* For prompt analysis and quotation on your requirements, send us your blue prints or specifications.

* *Bulletin available on request.*

INJECTION MOLDED MINNESOTA O-RINGS

The exclusive Minnesota injection molding process makes possible mass production economies while fulfilling extreme uniformity and tolerance requirements. Special attention is paid to O-Ring tensile strength and resistance to abrasion, compression set, hydraulic fluids, heat and cold.

Manufacturers of All Types of Small Rubber Parts

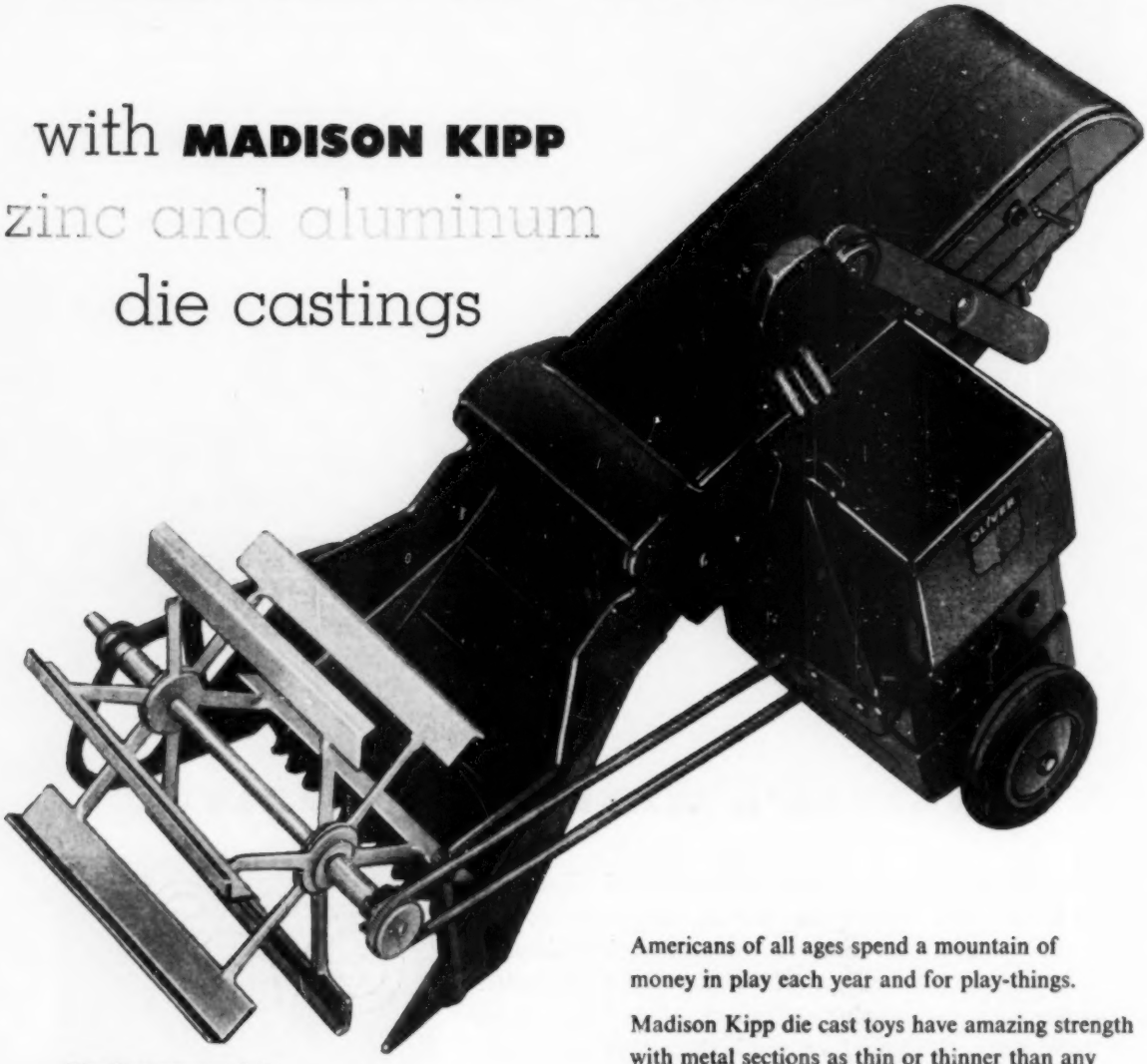
MINNESOTA RUBBER & GASKET COMPANY

3630 WOODDALE AVE., MINNEAPOLIS 16, MINN. • Phone WHittier 6511

AFFILIATED WITH MINNESOTA SILICONE RUBBER CO. • OFFICES IN PRINCIPAL CITIES

DESIGNING for "fun"

with **MADISON KIPP** zinc and aluminum die castings



Kipp die castings made for Lansing Company Incorporated, Lansing, Iowa

Americans of all ages spend a mountain of money in play each year and for play-things.

Madison Kipp die cast toys have amazing strength with metal sections as thin or thinner than any other castings produced out of aluminum.

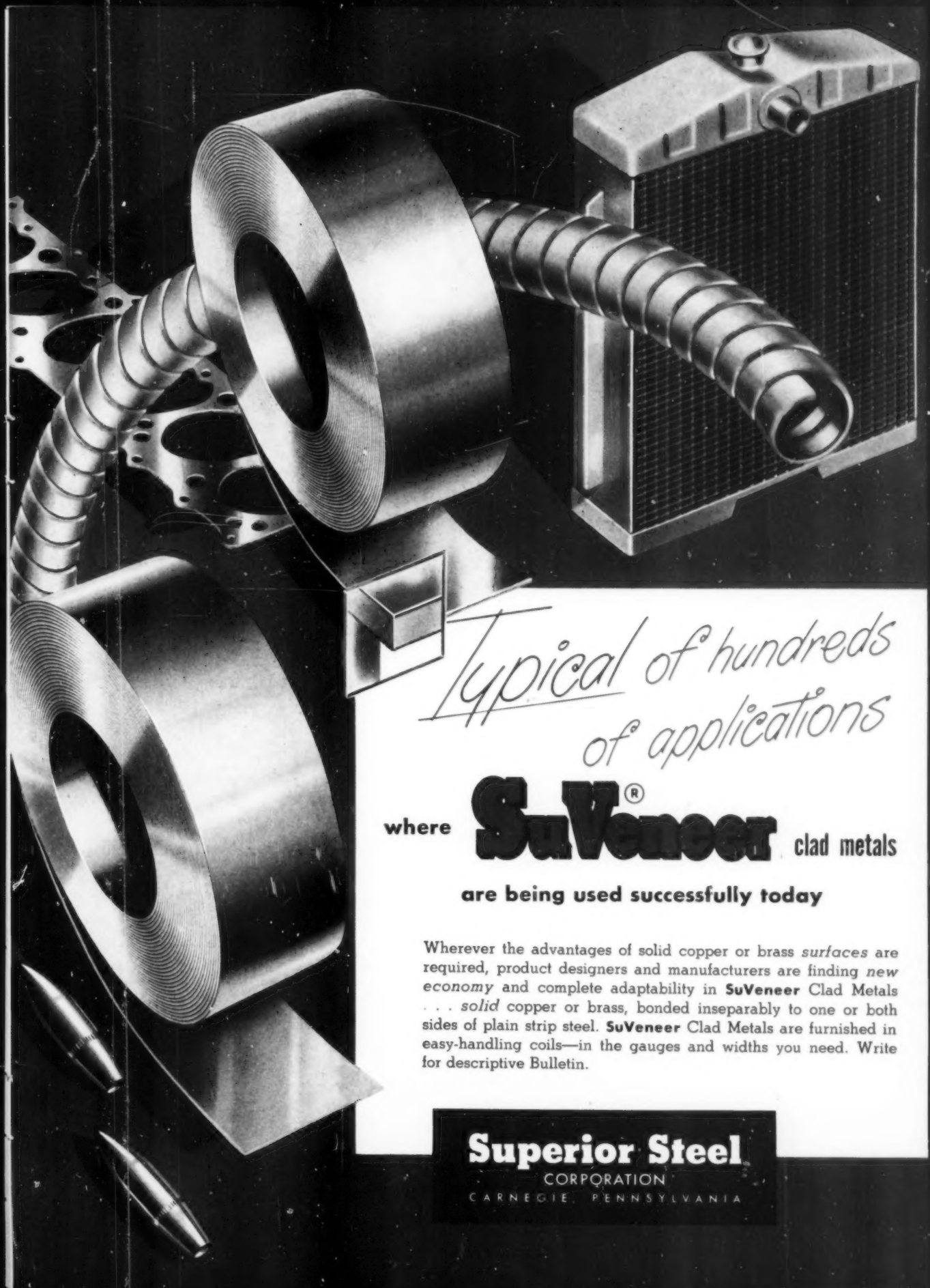
Designers of other commercial and ordnance products may find helpful hints from the engineers who design for the fun business.

Please send your inquiries to our home office in Madison, Wisconsin.

madison kipp corporation

MADISON-KIPP CORPORATION
706 WAUBESA STREET • MADISON 10, WIS., U.S.A.

• Skilled in Die Casting Mechanics • Experienced in Lubrication Engineering • Originators of Really High Speed Air Tools



Typical of hundreds of applications

where SuVeneer® clad metals

are being used successfully today

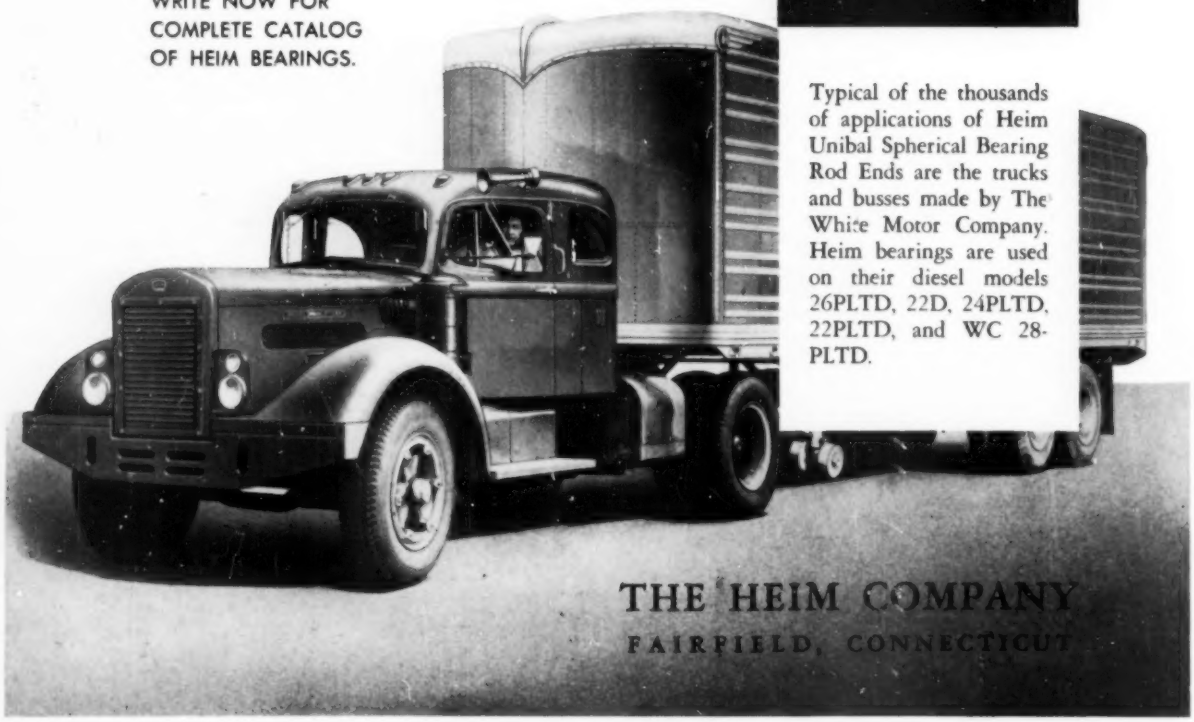
Wherever the advantages of solid copper or brass *surfaces* are required, product designers and manufacturers are finding *new economy* and complete adaptability in **SuVeneer** Clad Metals . . . *solid* copper or brass, bonded inseparably to one or both sides of plain strip steel. **SuVeneer** Clad Metals are furnished in easy-handling coils—in the gauges and widths you need. Write for descriptive Bulletin.

Superior Steel
CORPORATION
CARNEGIE, PENNSYLVANIA

HEIM ROD ENDS

A single ball revolving in spherical bronze bearing inserts provides a larger bearing surface so that maximum radial and thrust loads are carried by Heim Unibal Spherical Bearing Rod Ends. The universal motion of the ball corrects misalignment of the shaft, or stud, in all directions.

WRITE NOW FOR COMPLETE CATALOG OF HEIM BEARINGS.



Typical of the thousands of applications of Heim Unibal Spherical Bearing Rod Ends are the trucks and busses made by The White Motor Company. Heim bearings are used on their diesel models 26PLTD, 22D, 24PLTD, 22PLTD, and WC 28-PLTD.

THE HEIM COMPANY
FAIRFIELD, CONNECTICUT

Prove to yourself...

These are better AN connectors--and at competitive prices

BETTER...

...Because Monowatt *AN* Connectors have *all* these features:

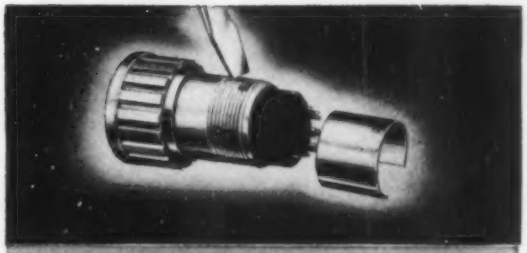
- ***Moisture-proof seal.*** Two-piece inserts are joined with a silicone sealing compound. Moisture and condensation effectively excluded... parts held together while inserts are soldered to cable assemblies.
- ***Diallyl Phthalate insert material*** (blue) used in all connectors. Negligible post-mold shrinkage... superior dielectric properties.
- ***Fewer parts and simpler design*** make installation and inspection easy.
- ***Cadmium-plated housings*** resist corrosion.
- ***Tellurium copper pins,*** heavily silver-plated, insure greater conductivity... 99% that of copper.
- ***Available in complete wiring harness or cable assemblies.*** Made by Monowatt to your specifications.

PRICED RIGHT...

...Because the Monowatt Department of General Electric has complete modern facilities for mass-production, these features are offered at competitive prices.

THE PROOF STARTS WITH THE QUOTATION

...*Prove to yourself* that Monowatt *AN* Connectors at competitive prices bring you extras—extras which save assembly time and insure a superior connecting job.

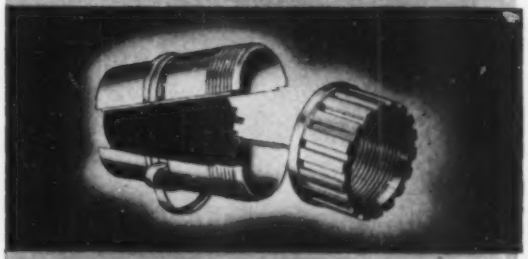


AN Solid Shell Connector

BETTER... because its snap-in retaining sleeve cannot work loose, yet can be released quickly with a screw driver and the insert removed for inspection or soldering.

AN Split-Shell 90° Angle Plug

BETTER... because top can be removed to inspect wiring without unmating or disassembling plug from conduit or cable. Conduit thread is not split. Split-shell ease of wiring is combined with advantages of solid shell construction.



AN Split-Shell Straight Plug

BETTER... because Monowatt engineers have succeeded in reducing number of metal parts and weight, while improving connector performance. This type is preferred where assembly must be made in tight places.

Send your specifications with this coupon. In return you'll receive a catalog describing the unique cost-saving features of Monowatt electrical connectors and wiring assemblies for aircraft, ordnance and electronic equipment — plus — quotations on your specific requirements. If you wish, a representative will call with sample connectors... all without cost or obligation.

MAIL COUPON AND YOUR SPECIFICATIONS TODAY.

MONOWATT

Monowatt Department B-1, General Electric Company
95 Hathaway St., Providence 7, R. I.

☐ Please quote on the attached specifications and send catalog.

☐ Please quote on the attached specifications and have your representative call with sample connectors.

☐ Please send catalog only.

I understand neither the quotation, catalog nor call obligates me in any way.

Name .....

Title .....

Firm .....

Street ..... Zone ..... State .....

City .....

A DEPARTMENT OF GENERAL ELECTRIC COMPANY, PROVIDENCE 7, R. I.

Squeezed like an accordion, welded tubing demonstrates uniform strength

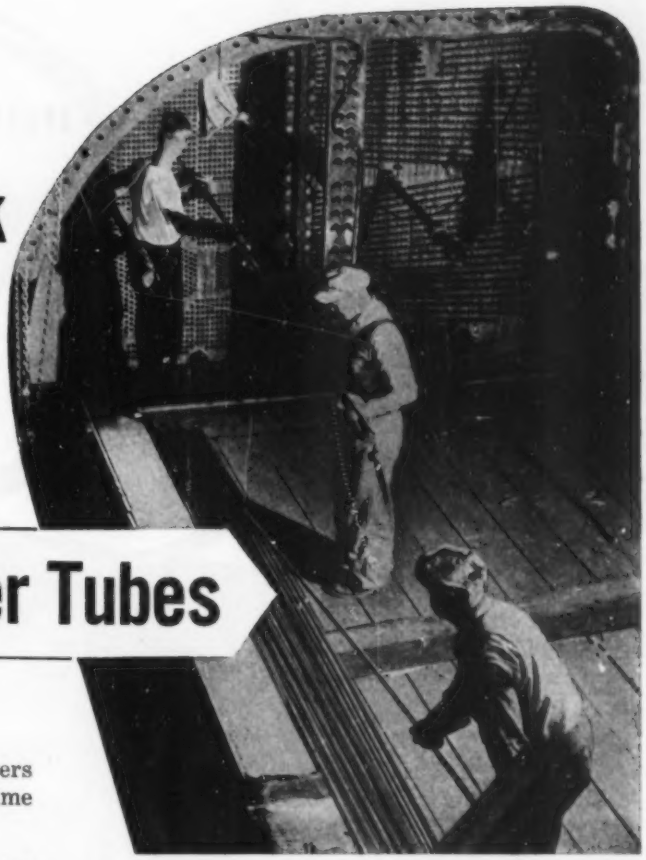
● This compression folding of a section of electric-welded steel tubing produces no cracks or flaws. Such uniform strength is proved in many other severe cold forming operations. U. S. Bureau of Standards tests show that the weld is as strong as the wall, and that it has the same qualities as the steel

Investigate the economy and physical advantages of Brainard welded steel tubing in *your* products. Write Brainard Steel Division, Dept. GG-1, Griswold Street, Warren, Ohio. An integrated producer; offices throughout the U. S.

Brainard
SHARONSTEEL
STEEL DIVISION
SHARON STEEL CORPORATION

WELDED STEEL TUBING

One Way to Lick Corrosion and Wear of Heat Exchanger Tubes



Anaconda 70-30 Cupro-Nickel Tubes, produced by AMERICAN BRASS COMPANY, Waterbury, Conn., were used to replace tubing of Admiralty Metal at the Harbor Steam Plant, Dept. of Water and Power, City of Los Angeles, Calif. View shows men retubing part of a 70,000 sq. ft. surface twin-condenser with 5,878 Anaconda cupro-nickel tubes ⅞" O.D. x 26' 3" long, serving a 75,000 KW turbine.

It takes a lot of handling to retube heat exchangers . . . and while the job goes on, equipment downtime plays mischief with production.

Minimize the risk of such shutdowns. Wherever heat-transfer capacity is a factor, especially where wall thickness of tubes allows but little tolerance for effects of corrosion and erosion, specify 70-30 cupro-nickel tubes.

Thin walls of this strong tough alloy resist corrosive and erosive attacks from all sorts of cooling media including polluted, silt-laden harbor water.

Along with ability to withstand a wide variety of corrosive agents, the 70-30 cupro-nickel tubing provides outstanding resistance to pitting and stress corrosion cracking.

* * *

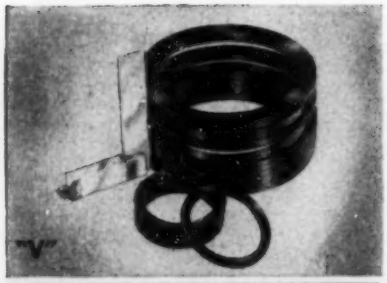
Aship or ashore, this alloy gives unsurpassed performance in vital parts of equipment exposed to salt water corrosion.

In power generator stations, sugar mills, oil refineries and similar plants . . . cupro-nickel alloys serve in feed water heaters, condensers, evaporators and other heat exchangers, and in oil coolers, stills, water boxes, piping, tanks, and other equipment. Cupro-nickel alloys minimize maintenance and replacement expense, loss of heat transfer capacity and interruptions of operation resulting from corrosion.

Cupro-nickel is produced in tubing, rod, strip, wire and sheet, and also in cast form. We shall be glad to give you additional information and help you select the one best suited to your requirements. Write us today.

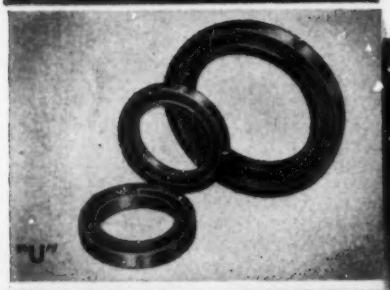
At the present time, nickel is available for the production of cupro-nickel and other alloys containing nickel, for end uses in defense and defense supporting industries. The remainder of the supply is available for some civilian applications and governmental stockpiling.

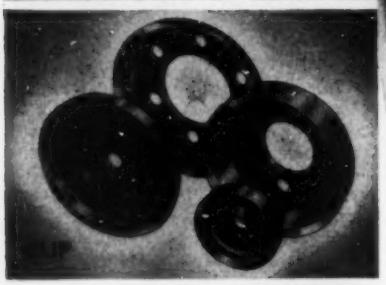
THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

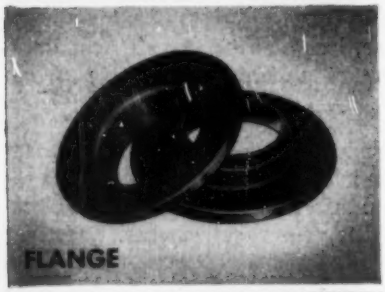


O-RINGS

Made of rubber. Self-sealing for single or double action. Excellent for pressures under 1500 psi. Applied with leather back-up rings, can be used with pressures over 1500 psi when engineered correctly. Installed in groove in rod gland or piston head; also used as a static seal.

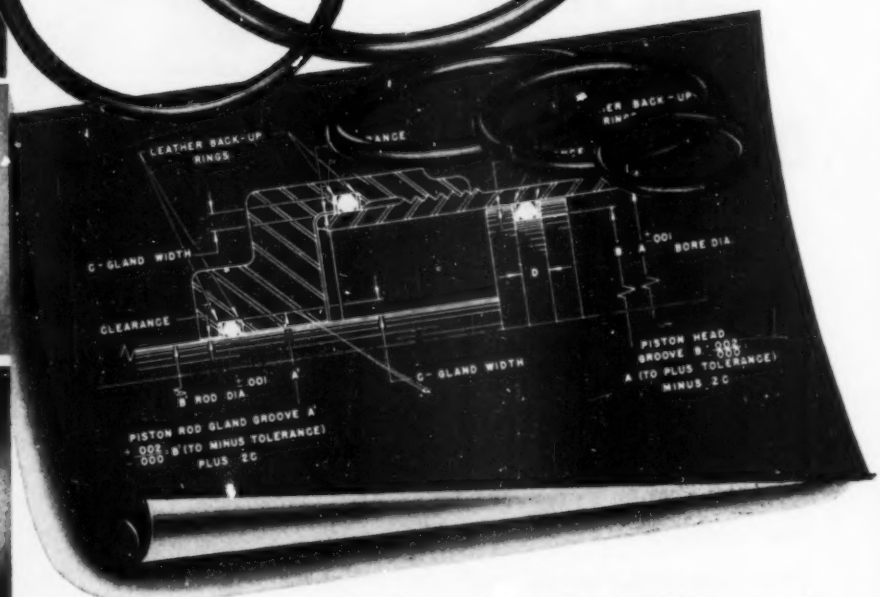






G&K—INTERNATIONAL Packings Specialists,

offering leather and synthetic rubber for your needs



There's one *right* packing for each application . . . *and only one.* Because, in the packings business, there is no such thing as "just as good." It's a precision business where knowledge and experience count.

That's why you can be sure when you bring your packings specs to G&K-INTERNATIONAL, the packings specialists. One entire plant and personnel are devoted solely to the design, engineering and manufacture of leather and/or synthetic rubber packings.

All standard packings types of leather or synthetic rubber can be ordered to JIC Standards for Original Equipment or Replacement. For special jobs send details. You'll get prompt service.

NEW O-RING BOOKLET FREE

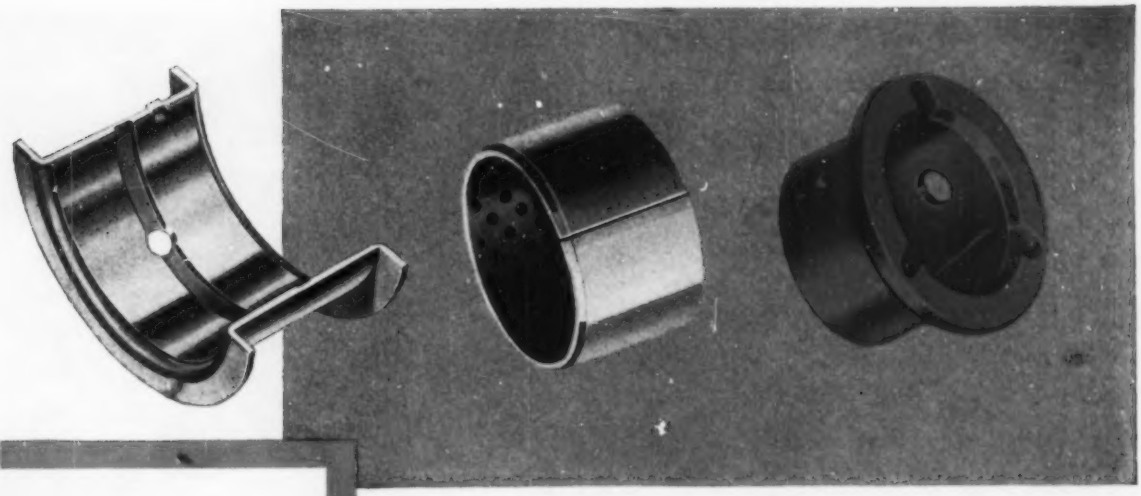
Up-to-date tables covering basic rubbers and approved compounds, dimensional data and installation detail. A right-hand reference manual for design engineers. Write for it now — it's free.

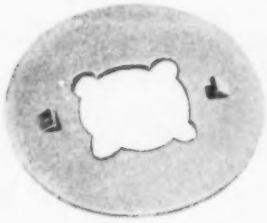
G&K GRATON AND KNIGHT INTERNATIONAL

GRATON & KNIGHT COMPANY
Established 1851
Worcester 4, Massachusetts

INTERNATIONAL PACKINGS CORPORATION
Graton & Knight Company Affiliate
Bristol, New Hampshire

P-1





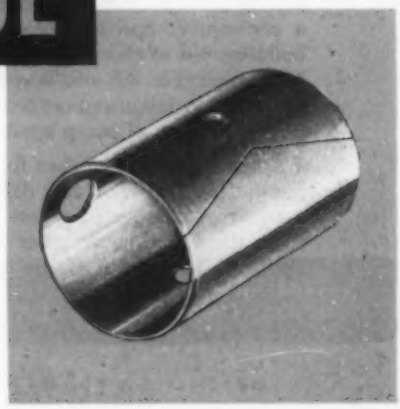
Products of our six plants include: Sleeve bearings in all designs and sizes; cast bronze bushings; rolled split-type bushings; bi-metallic rolled bushings; washers; spacer tubes; precision bronze parts and bronze bars.

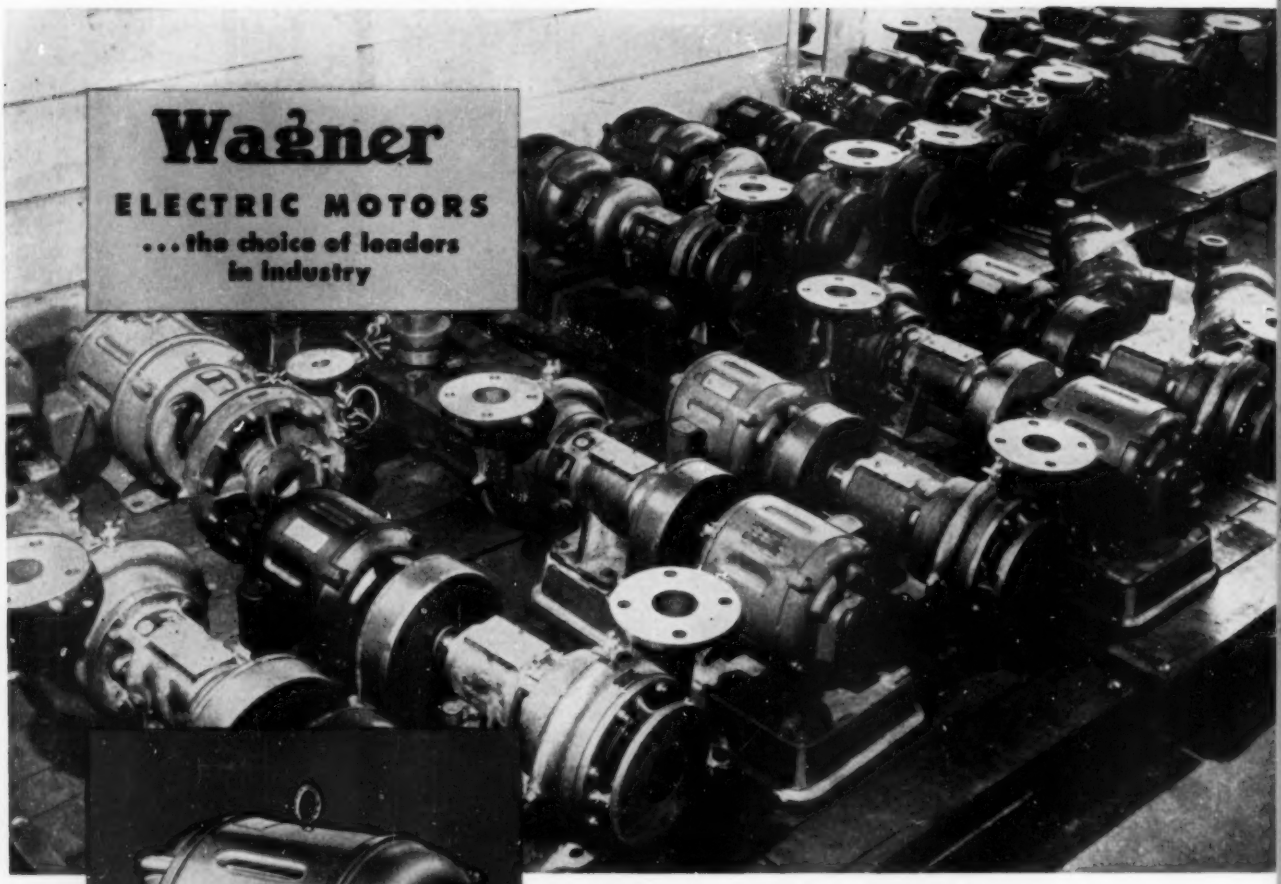
SINCE 1899

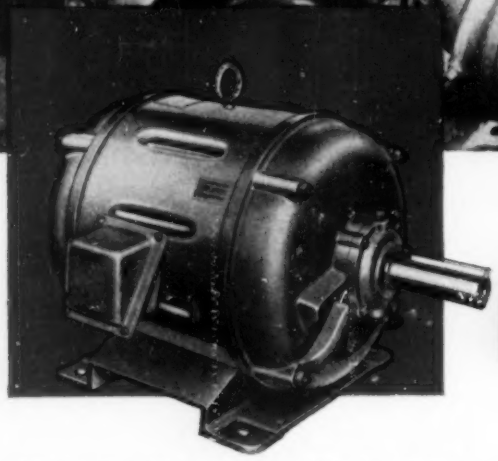
FEDERAL-MOGUL

FEDERAL-MOGUL CORPORATION

11043 SHOEMAKER, DETROIT 13, MICH.







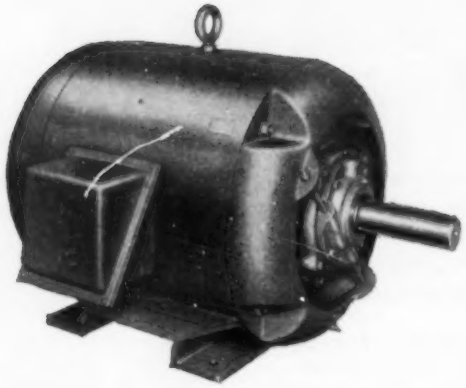
Wagner motors

Motors that drive pumps need plenty of electrical and mechanical stamina to hold up under the hard steady grind expected of them.

Fitting the right motor to your pumps is not a problem of special motor designing and building, but of choosing a standard Wagner Motor suited to the job. Wagner Motors are diversified in design and can be readily adapted to a wide range of pump applications.

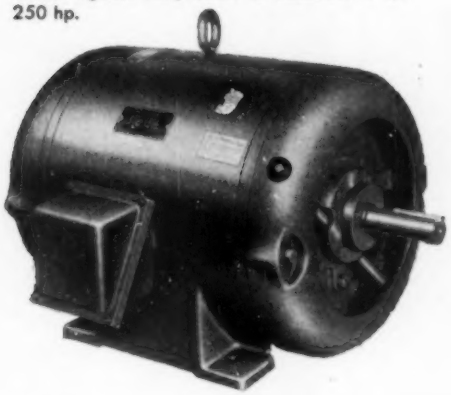
Wagner Motors are chosen for thousands of pumps because they can deliver plenty of sure, easy, continuous power. They require very little attention—Wagner Motors are designed to keep maintenance at a minimum. They give the kind of service you want—more than sixty years of motor building experience stands behind every motor bearing the Wagner name.

The Wagner open type, ball bearing, polyphase squirrel-cage motor shown above is dripproof and is available in ratings from 1/6 to 400 hp. Integral horsepower squirrel-cage motors, in open, totally-enclosed non-ventilated and totally-enclosed fan-cooled construction, can be supplied with face type and flange type endplates for vertical or horizontal operation. Four other motors from the complete Wagner line are shown on the opposite page.

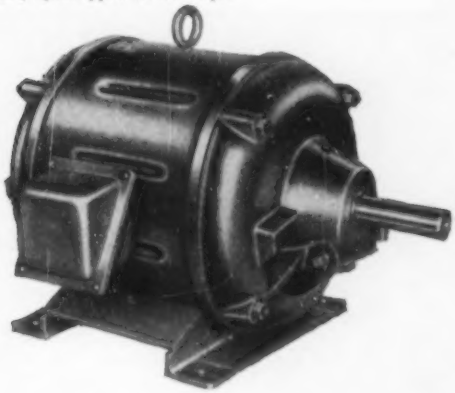


Type CP—Totally-enclosed Fan-cooled. Protected against dirt, fumes or moisture. 1 to 250 hp.

Jet Pump Motors—Single phase, capacitor-start, open type. ¼ to 1 hp.



Type EP—Corrosion-resistant cast iron. Totally-enclosed Fan-cooled. 2 to 250 hp.



Type RP—Open type, sleeve bearing, polyphase squirrel cage. 1/6 to 400 hp.

furnish plenty of power for pumps...

Improve the performance, economy and dependability of your product by choosing Wagner Motors. Bulletin MU-185 gives information on the complete line. Let a Wagner engineer discuss your motor needs with you. Consult the nearest of our 32 branch offices, or write us.

it's to your advantage to standardize with Wagner:

When you standardize on Wagner Motors—you get the advantages of a liberal warranty . . . of nationwide service facilities, with on-the-spot service, replacement motors and parts available from 25 Wagner-owned Service Branches and more than 750 Authorized Service Stations. You can choose from a wide variety of types and sizes (from 1/125 to 400 hp).

WAGNER ELECTRIC CORPORATION
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ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES
AUTOMOTIVE BRAKE SYSTEMS—AIR AND HYDRAULIC

BRANCHES IN 32 PRINCIPAL CITIES

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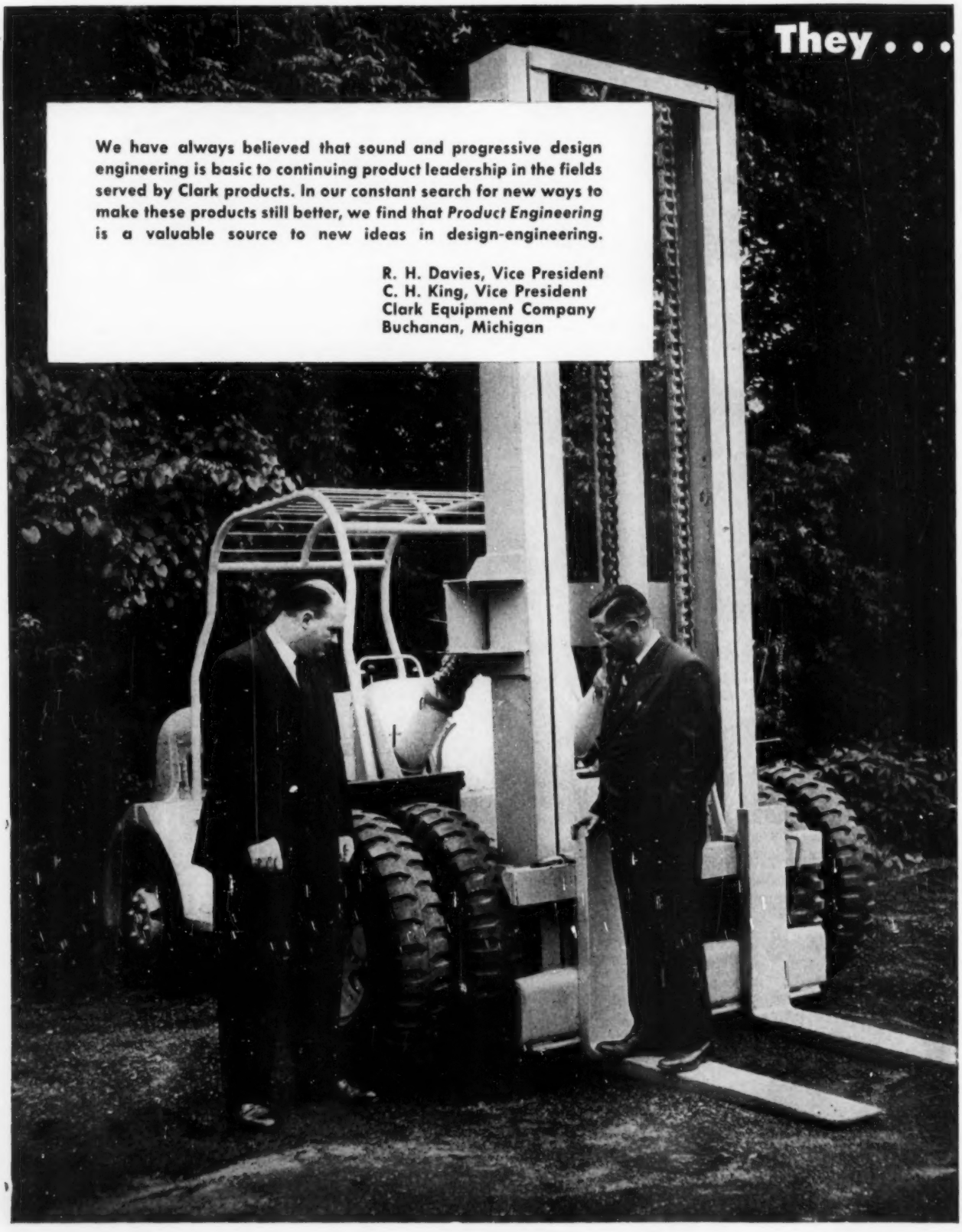
They . . .
We have always believed that sound and progressive design engineering is basic to continuing product leadership in the fields served by Clark products. In our constant search for new ways to make these products still better, we find that *Product Engineering* is a valuable source to new ideas in design-engineering.
R. H. Davies, Vice President
C. H. King, Vice President
Clark Equipment Company
Buchanan, Michigan

THE MEN WHO DESIGN

. . spearhead product development at Clark

THEY READ PRODUCT ENGINEERING

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Over 800 companies are currently building bigger markets for their products in the advertising pages of *Product Engineering*. They accept this magazine, on a basis of proved values and their own sales experience, as the leading medium in the giant Original Equipment Market . . . and invest far more advertising dollars and pages in it than are invested in any other design publication.

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They pay to read *Product Engineering* because reading it *pays them* handsome dividends in increased knowledge and inspiration. Nowhere else in all the world can product-design engineers find so much information specifically useful to them as they find in this magazine's helpful, far-sighted pages.*

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*With introduction this year of the Annual HANDBOOK of Product Design, *Product Engineering's* service to its readers takes another great step forward. The Annual HANDBOOK will now be published each November. Ask your *Product Engineering* representative to show you the Annual HANDBOOK of Product Design for 1953, and to discuss with you the important place in your 1953 advertising plans next year's issue should occupy.

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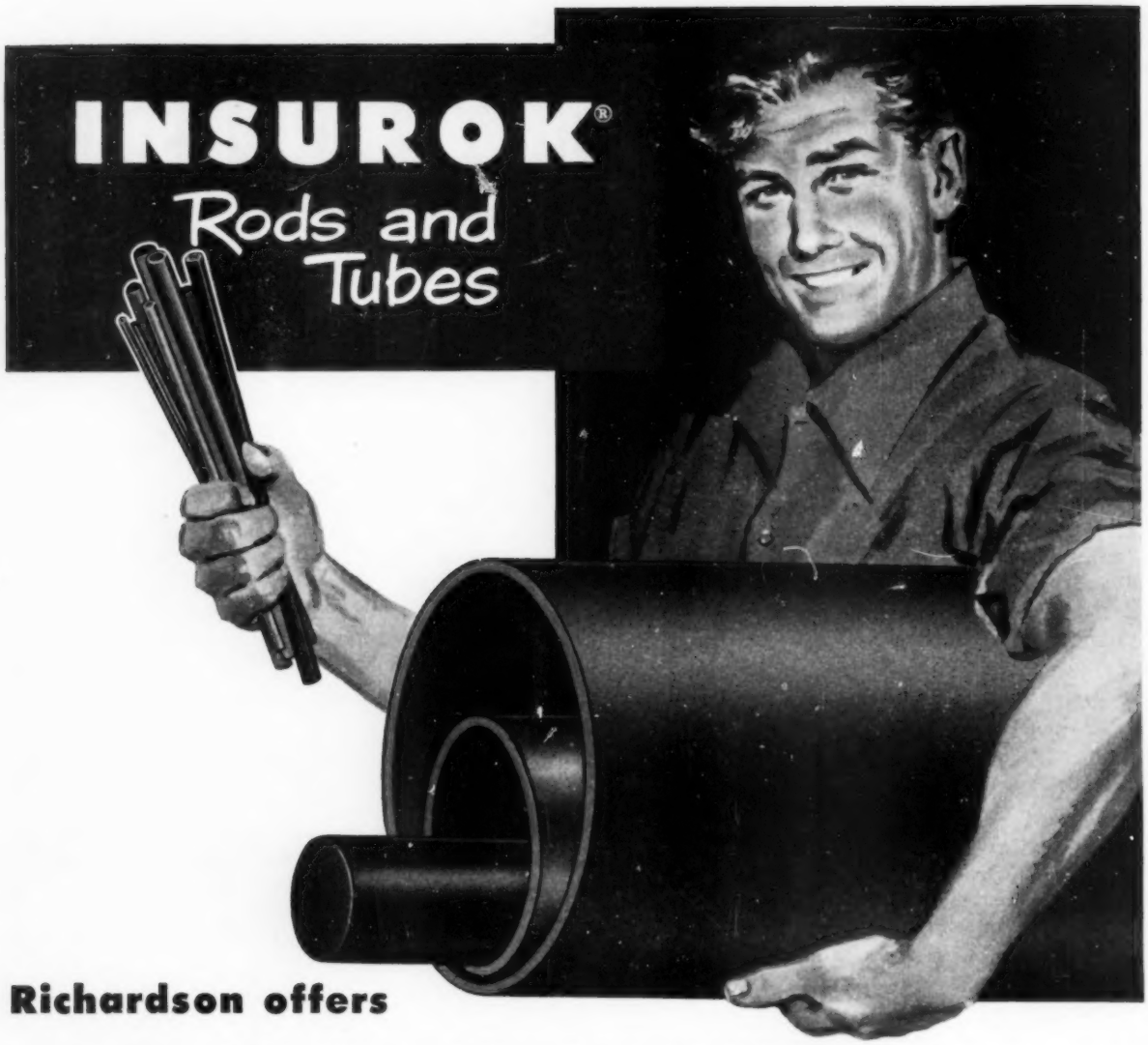
AMERICA'S NEW PRODUCTS READ PRODUCT ENGINEERING

INSUROK®
Rods and Tubes



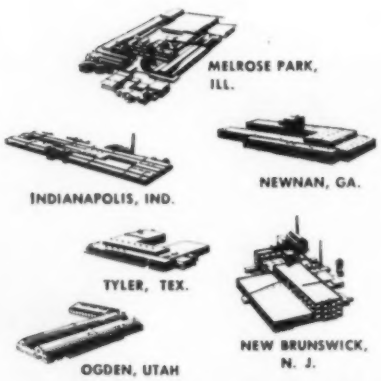
Richardson offers

a complete line of Laminated Plastic

Rods and Tubes to meet your needs

You'll find a large range of laminated plastic rods and tubes of various diameters in the Richardson line. Laminated tubes are available in fabric-base and paper-base grades, in 36" lengths and in diameters from 1/8" to 12 1/2". Special larger sizes can be made upon request. Laminated rods are available in molded-paper or fabric-base grades in diameters from 1/8" to 2". Diameters from 2" to 6" can be machined from sheet stock.

Whatever your plastics requirements, consult The Richardson Company. Richardson offers a *complete* plastics service—embracing materials development, design, molding, laminating, and fabricating. Write for 20-page booklet—"Laminated INSUROK."



The RICHARDSON COMPANY

FOUNDED 1858 — LOCKLAND, OHIO

2793 Lake St., Melrose Park, Illinois (Chicago District)

Perspectives ~ DESIGN AND DEVELOPMENT

MAGNESIUM DEVELOPMENTS

The progress of the magnesium industry has been somewhat overshadowed by the glamorous advent of titanium into the light metals field. However, steady technological development and its good availability during the recent critical period have brought magnesium a long way in a comparatively short time.

Some of the more recent metallurgical and production improvements that are expected to further increase the use and effectiveness of magnesium were discussed at the Magnesium Association meeting in New York in October. These include: development of new methods of grain refinement to improve the mechanical properties; the use of improved sand casting techniques to produce large castings; development of large forging presses and the introduction of the shell mold and investment casting processes for production of precision magnesium parts.

GRAIN REFINEMENT

Magnesium alloy castings generally have a coarse grain structure and low mechanical properties, necessitating some means of grain refinement. This has been effected by superheating the molten metal prior to cooling to the pouring temperature. Inconsistency of results and the time consumed in superheating and cooling are the major disadvantages of this method. Experimental work in grain refinement by introducing chlorinated solid hydrocarbons into the melt has shown very favorable results. It is expected that this method will effect considerable savings in production and will insure a casting with consistent tensile properties -- a definite design advantage.

LARGE CASTINGS AND FORGINGS

The pressure put on the aircraft industries by the Air Force has reresulted in the development of techniques for producing large castings and forgings. Radar equipment and guided missiles require very large cast parts. One of the largest magnesium castings now in production by the Rolle Mfg. Co., measures 90 x 100 inches by 33 inches deep and weighs 1620 pounds.

The R. H. Osbrink Mfg. Co. is producing large thin-walled magnesium castings for units formerly fabricated from dural sheet, with no increase in weight. For instance, a unit that at present is made from 0.051 inch sheet dural and riveted together can be made with a 1/10 inch cast wall. The net weight would be about the same when the weight of lap joints, rivets and stiffners joining the sheet assembly are considered.

Initial tooling costs of blanking dies, forming dies, assembly fixtures, etc. needed for production of fabricated parts are often more than ten times as high as pattern tooling costs for castings. The unit cost of a cast part is also less than the fabricated part.

The use of large thin-walled castings allows for the production of complicated integral units normally impossible or extremely difficult to obtain by fabrication from sheet. The cast unit also has higher rigidity than the fabricated unit.

The mechanical properties of magnesium casting alloys have been found to increase as the cross section decreases. Further investigation into this condition is expected to reveal that higher allowables in stress analysis and calculation can be used by design engineers.

(Continued on page 117)

No room for guesswork HERE

complete modern laboratories make sure that FLEXON BELLOWS will meet your requirements

The mass spectrometer pictured above is only one of the modern devices used by Flexonics Corporation to verify the high quality of FLEXON Bellows and give assurance that they will meet your specifications. This laboratory background coupled with bellows manufacturing skill provides a complete service to all manufacturers who use bellows in their products.

FLEXON Bellows are made in brass, bronze and stainless steel in a complete range of sizes. When required, bellows assemblies can also be furnished.

For complete information and recommendations, send an outline of your needs.

The FLEXON Bellows Design Guide gives full information on FLEXON Bellows as well as useful data on selection of bellows. Write for a copy.

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Flexon identifies products of Flexonics Corporation that have served industry for over 50 years.

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In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

AIRCRAFT WINGS

An interesting example of the use of large magnesium castings is the experimental aircraft wing section produced by the cooperative efforts of Northrup Aircraft and The Aluminum Company of America. This wing section is made in two halves, upper and lower, which are fastened in clamshell fashion. Each section is 16 feet long, 43 inches wide and weighs about 200 pounds. Section thickness varies from 1/4 to 1/2 inch. Recesses are cast into each half for joining skin sheet. The airfoil shape is cast to dimensions, with no finishing required other than sand blasting.

The heavy press program, sponsored by the U. S. Air Force with the full cooperation of press manufacturers and materials suppliers, is responsible for the tremendous strides being made in the production of large magnesium forgings. Many cost and functional advantages are obtained through producing large structural parts in one piece.

The shell molding process has shown promise for production of magnesium castings of limited size. There are still some difficulties, such as shake-out and odor, that have to be ironed out but these are not expected to be in any way insurmountable. Advantages to be expected from the use of this process are close tolerances, smooth finish, higher production at lower cost and reduction of scrap losses.

MAGNESIUM IN THE B-36

The use of magnesium in aircraft has been increasing steadily and is expected to continue on the uprise. Magnesium alloys have been of great value in the B-36 program, since in a plane of this size a considerable portion of the structure presents "minimum gage" problems. Magnesium provides the necessary structural stability at absolute minimum weight.

Estimates of the quantity of magnesium alloys currently used in the B-36 are: 8,300 pounds of sheet and extrusions in the airflame, 600 pounds of castings in airframe and equipment; 1,710 pounds in wheel castings, 3,048 pounds in power plants, 432 pounds in the propellers spinners; 1,480 pounds in the turrets and 100 pounds in miscellaneous equipment -- a total of 15,670 pounds.

SUPPLY AND DEMAND

As far as the supply of magnesium is concerned there has been a drastic change within the past year. According to Dow Chemical Co. production is now more than double the actual consumption. The annual production rate is now over 100,000 tons while consumption runs about 45,000 tons per year. The surplus is at present going into the government stockpile which had been at a very low level since the beginning of the Korean War.

One major factor in the sudden rise in production was the reactivation of six Government-owned plants to meet military requirements. Some of these plants, probably those not using the electrolytic method for producing magnesium, will probably be closed down.

This ready availability of magnesium is expected to stimulate interest in its application potential. The military services are beginning to encourage greater use of the metal and commercial industries will no doubt follow suit. Two industries offering a potential large market for magnesium are the materials handling and highway transportation industries. It has been estimated that if all trailer, truck and bus bodies were made of magnesium annual requirements would total 155 million pounds of extrusions, sheet and plate and castings. Many of these applications would no doubt be prohibitive because of design limitations or the poor corrosion resistance of magnesium. However, a large potential market still exists in the transportation field and in other fields where lighter weight would result in reduced operating costs.

Jackson TELEVISION

Channels 63% Savings

WITH TINNERMAN SPEED NUTS®

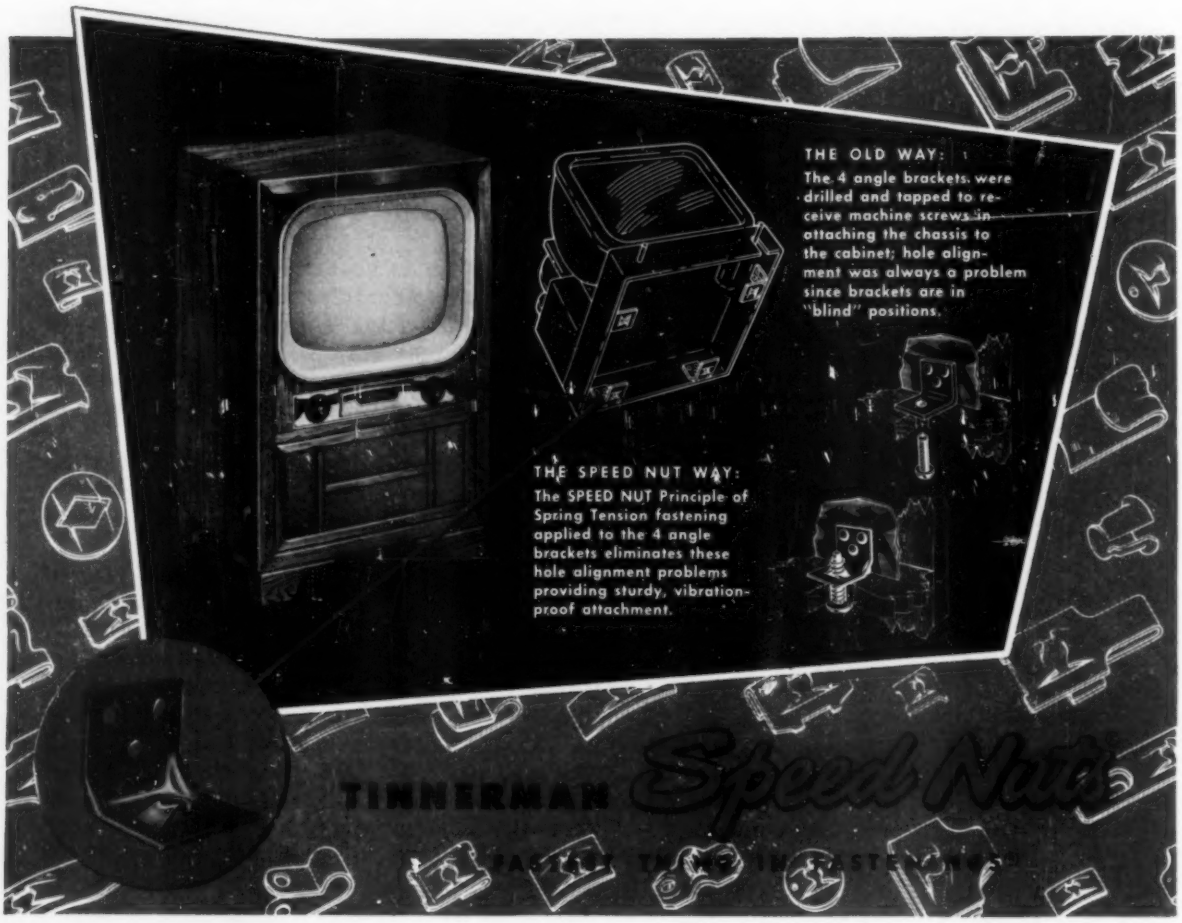
● Engineers at Jackson Industries, Inc., Chicago, Ill. are "on the beam" when it comes to maintaining TV quality at production line speeds. They found the SPEED NUT way of attaching their new Tri-Lok television chassis to the cabinet picked up a neat 63% production savings! This attachment was one of their toughest fastening problems... to solve it Jackson found a standard Tinnerman part tailor-made and engineered for the job!

Four angle brackets are used to fasten the chassis to the cabinet. In the old way, an angle bracket was threaded to receive a machine screw, and it was necessary to align the screws perfectly with the threaded holes since the attachment is in a "blind" position.

SPEED NUTS eliminate the tapping operation required in threading the angle brackets, making hole alignment easier, faster! Now Jackson has adapted this part into their standards along with a 63% savings in time and materials-handling!

You can turn your fastening problems into production savings... do as thousands of manufacturers are doing ...turn to Tinnerman for a FREE FASTENING ANALYSIS of your products. The Tinnerman representative in your area will be happy to give you the full details on this great service. Call on him today or write direct to: TINNERMAN PRODUCTS, INC., Dept. 12, Box 6688, Cleveland 1, Ohio.

In Canada. Dominion Fasteners Ltd., Hamilton, Ontario. *In Great Britain*: Simmonds Aerocessories, Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S.A.—7 rue Henry Barbusse, Levallois (Seine.)


THE OLD WAY:
The 4 angle brackets were drilled and tapped to receive machine screws in attaching the chassis to the cabinet; hole alignment was always a problem since brackets are in "blind" positions.
THE SPEED NUT WAY:
The SPEED NUT Principle of Spring Tension fastening applied to the 4 angle brackets eliminates these hole alignment problems providing sturdy, vibration-proof attachment.
TINNERMAN Speed Nuts

The Chariot to Fame and Glory

THE ROAD TO PROFESSIONAL FAME AND GLORY is rough and rugged only for those who fail to analyze the project. For a ride free of discomfort, all that is needed is the right kind of a vehicle, one that will absorb the bumps and pass all traffic. Such a vehicle is at the disposal of anyone who has a pencil and some paper.

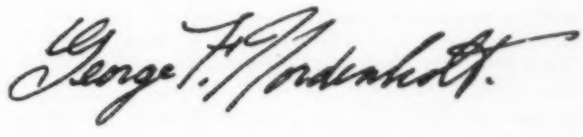
Professional fame is the same as any other kind of fame. It is nothing more than being talked about favorably by a great number of people. If the talk is unfavorable, the person is not famous, he is notorious. Hence the problem of the man who wants to become famous is how to get many people to talk about him with admiration, awe, reverence or perhaps even a tinge of envy.

The business of advertising and publicity agencies is to make persons, products or projects famous. The general methods and techniques employed are well known. But only the exceptionally wealthy individual could afford to employ commercial advertising techniques to make him famous. Fortunately, other and more economical means are available, namely, making speeches and writing.

Many engineers have sought fame and glory through the medium of speeches and writing, and have failed. A careful analysis will usually show that the individual failed in meeting one essential requirement. He did not use the right words. He used simple understandable everyday language. Hence he did not sound awesome, authoritative or original.

The first step to fame for the man who really has nothing that truly deserves fame is a strange sounding vocabulary. The second essential is to weave the words together into musical flowing sentences that lull the senses of discernment and make no sense. The moment the speech or writing becomes meaningful it will be open to discussion and criticism. That is bad because it will then be soon revealed that the whole diatribe is just humbug. The author will become notorious instead of famous.

In all professional groups and commercial circles, there are those who constantly seek to introduce new words, new concepts or novel philosophies that have no basis in fact. The membership of the profession, therefore, must always be watchful and ready to combat the mysterious indescribable new ideas and the fellow professional who claims his discoveries are beyond the comprehension of even the greatest authorities. To prevent the professional literature from becoming terribly cluttered with the barking of the side-show artist, articles or papers that do not make sense should not be accepted for presentation at a professional society meeting or published in the literature of the society.



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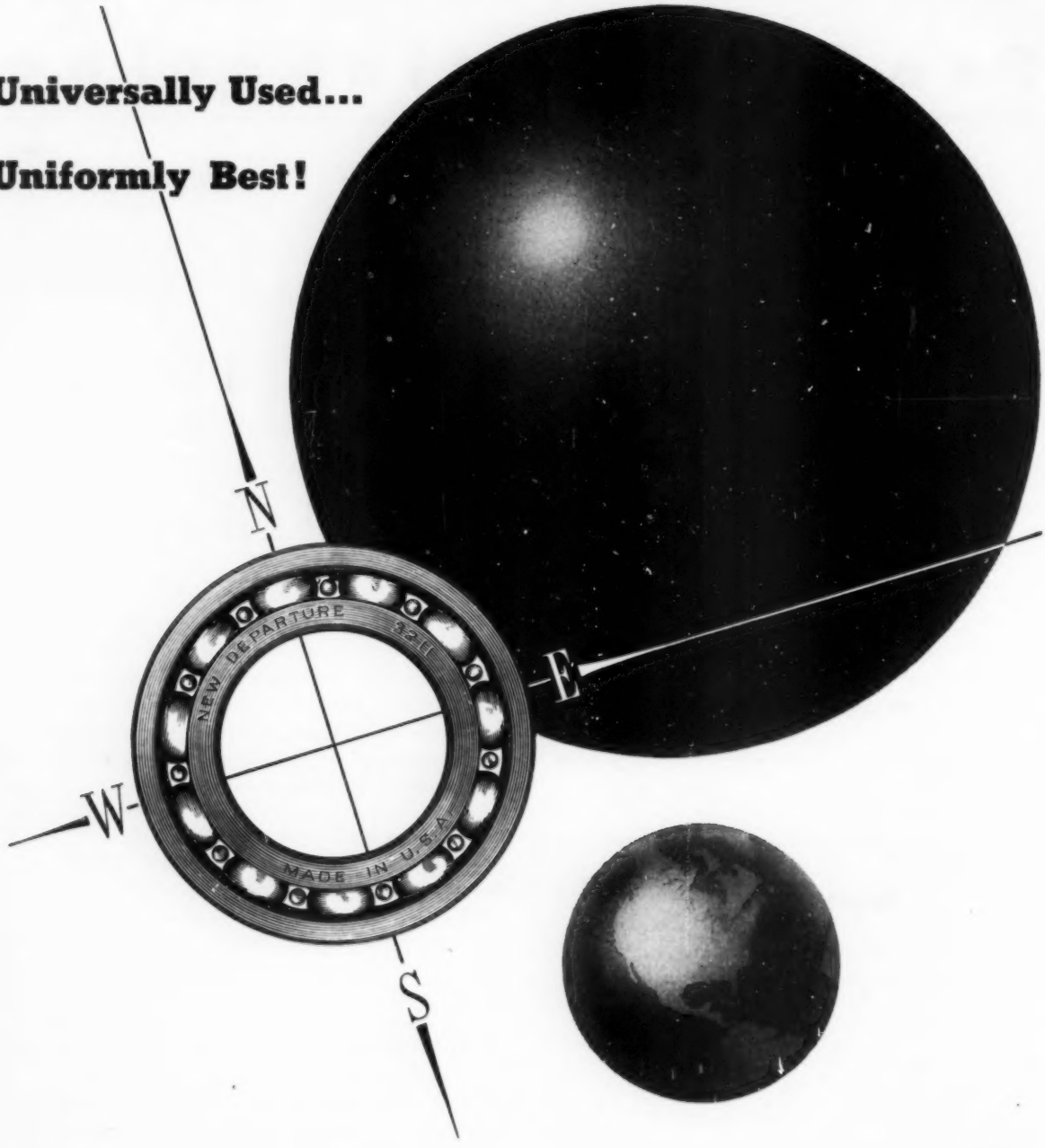
Uniformly Best!



• Throughout the world, New Departure ball bearings are in universal use . . . in motor vehicles and machinery . . . in instruments and implements . . . in conveyor lines and textile looms. Providing support for moving parts, they reduce friction, wear and maintenance . . . permit bigger loads and better design.

• Sixty years of research, engineering and production experience back up the New Departure name. Whether it's a jewel-like instrument bearing, or a giant, New Departure can build it best!

• New Departure's sales engineering staff is always ready to apply its experience to your particular problem.

• New Departure bearings are quickly available at your equipment dealer or bearing distributor—supplied from the industry's largest network of warehouse stocks.

NOTHING ROLLS LIKE A BALL

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BALL BEARINGS

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

Also Makers of the Famous New Departure Safety Brake

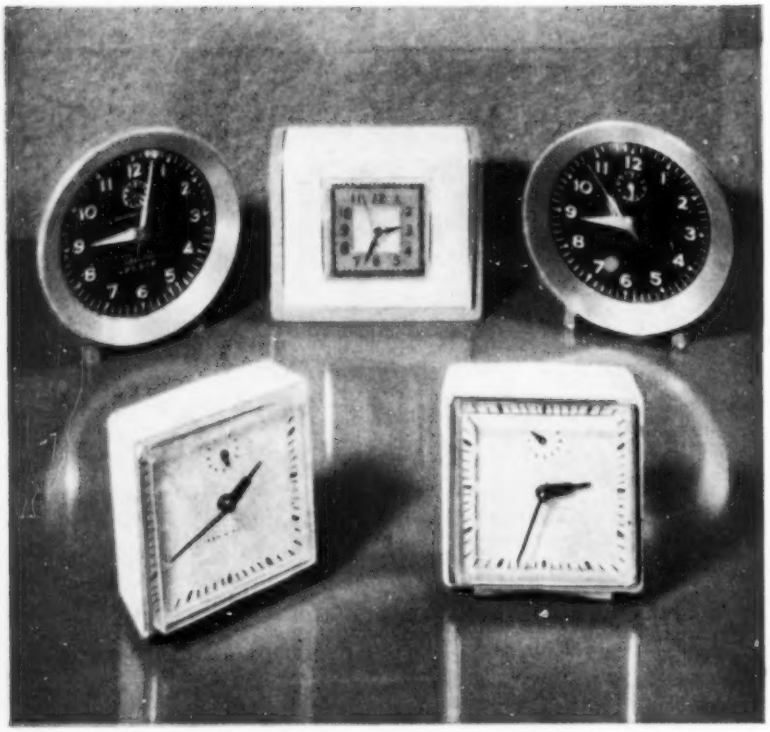
THE MECHANICS OF INDUSTRIAL DESIGN

Transposing an idea into a finished product involves not only the use of engineering drawings but—with form as well as function becoming increasingly important—such illustrative techniques as renderings in crayon and smootch, chalk sketches, scale and full size models, and other types of pictorial presentations.

These techniques, although closely associated with the industrial designer, are also useful engineering tools. Their advantages and limitations, and the methods for transposing them into engineering drawings, are herein discussed by Julian Everett and Robert Hose of the Henry Dreyfuss organization, whose experience is based on work for such clients as Bell Telephone Laboratories, American Machine and Foundry, The Hoover Company, Lockheed Aircraft, and RCA.

Naturally the techniques employed depend on the nature of the product as well as on the materials from which it is made. Small consumer products may require not only finished artwork, working drawings, and models, but also development of working prototypes made to specified dimensions and of specified materials. Large industrial equipment usually is approached in an entirely different manner.

And, of course, the techniques also may be governed by individual or organizational preferences.



FINAL PRE-PRODUCTION and production models of several E. Ingraham Co. clocks. They are, from left to right (top) production model of "Flair" spring wound clock, early presentation model of electric alarm clock, presentation model "Flair"; production model of Little Star spring wound clock (bottom) and presentation model. Development sketches on these and other models are shown on the preceding page.

FOR the most part, industrial design contributions in the field of product development relate to the several intangibles associated with merchandising and product character. In addition, the physical and psychological relationship between the product and the consumer are involved. In order to convert this type of thinking into product reality, the industrial designer must work intimately with groups of varying backgrounds, including management, sales, engineering and production. Of necessity, he must employ several media to illustrate his generic thinking as well as to diagram his specific solutions. For this reason, the designer utilizes several common, as well as a few unique methods of illustrating his design thinking as it progresses from the "idea" to the production stage.

While such methods are helpful in checking proportion and form, in establishing highlights that define form, in determining required changes prior to tooling and production, and in allowing full three dimensional visualization for all levels of management concerned with the product, a great many diversified steps are taken to bridge the gap between the initial design idea and the finished product. Different projects must be treated in different ways. Each individual job suggests and sometimes dictates the nature of its solution.

Large, heavy, massive machinery, for example, is not so much a problem of detail finesse—although this is often a part—as of total volumetric form, in which a proper relation of moving to fixed parts be found. Rough sketches, layout drawings, preliminary clay models and final appearance models at small scale are usually used to study a job of this nature. It is not important that full size graphic or three dimensional studies be made since all components are relatively large and generally simple.

On the other hand, the small product bought over-the-counter may very well be primarily a matter of detail finesse, correctly overlayed on a form suitably adapted to the end use. With a clock, for example, it is mandatory that all work be done accurately and to full or larger scale to prevent misconceptions regarding the final appearance.

The Initial Steps

In either case, whether the work is to be concerned with massive equipments or small products, the first steps are directed toward preliminary research. Not only must the requirements of engineering and the objectives of sales and management personnel be ascertained, but production limitations in the factory and comparisons with competitive products must be obtained.

In the process of resolving these various opinions and facts, it is desirable to employ freehand sketches to visually coordinate the various factors that are involved.

There are usually three steps taken with respect to sketches: (1) the "rough", (usually done in black and white and some colored pencil), (2) the semi-finished or "chalk" sketch. (which is fairly accurate and usually done in colored pencil), and (3) the "rendering" or presentation sketch. (which, is thorough, accurate, and done in media such as colored pencil, "smootch", air brush, water color, or tempera.)

Rough Sketches tend to stimulate design thinking, and by inter-relationship provide a basis for more factual and detail study. They are seldom used for presentation purposes but are often employed as a discussion medium within the design office as well as between the designer and members of the manufacturing organization.

Since many "roughs" may be drawn of a complex machine and related components before arriving at a few that are worth serious consideration, the sketches are usually rapidly made in perspective with soft pencil or colored crayon. While either conventional sketch pads or thin tracing paper can be used, the latter often saves time when the design is to be advanced from one illustrative stage to another.

Very thin (transparent) paper also is invaluable where the industrial designer is using colored pencils for overlay work. Where white is used to obtain contrast with other colors, the thin paper allows the white to show through with reasonable clarity. In the same way, it can be used as overlay with rough graphite or charcoal sketches. The graphite or charcoal can be used to block out the general form of a product, which will then show through the transparent overlay and allow the designer to visualize the shape and proportions before putting lines on paper.

In studying design ideas having color contrast, requiring material contrast (shiny to dull), or utilizing clear or opaque plastics, colored pencils are

helpful. The use of white crayon lines on a frosted surface transparent tracing, paper for perspective layout work, being less definite than black pencil lines, seems to offer less mental resistance to changing the line, form or perspective of the sketched object. Too, other colored pencils work well over the white lines, and if the design thinking developed in sketch form with white crayon seems worthy, it can quickly and easily be brought within more positive boundaries through the use of black pencil.

"Chalk" Drawings are greater in detail than the "roughs" and as a matter of fact, may be finished study sketches of various components of an assembly. Besides tracing paper, cover stock is sometimes used for these "rapid renderings", which are employed where form is more important than detail. It has better texture than many so-called "pastel" or "charcoal" papers, and being heavier, is easier to erase and easier to handle. Accurate perspective drawings at this stage provide quick visualization of three-dimensional bulk and the relationship between functional components of an assembly. Sketches can be quite rough, in the sense of simplicity, but attention should be given to keeping proportions fairly accurate and in relative scale.

Several techniques may be employed here. Most utilize color either in the drawing medium or in the paper on which the sketch is to be made. Colored sketches tend to get basic ideas across much more effectively than black-and-white. The appearance relationships of textures and materials can be suggested through the use of color such as brown for wood or white for metal. Also, since color so vitally affects the appearance and often the sale of a product, factors of hue, light reflection and refraction, and the relative emphasis or "weight" of color areas must be visualized and illustrated. The advantage of a tinted, rather than a white sheet is that tonal qualities can be imparted to the product without shading in the background.

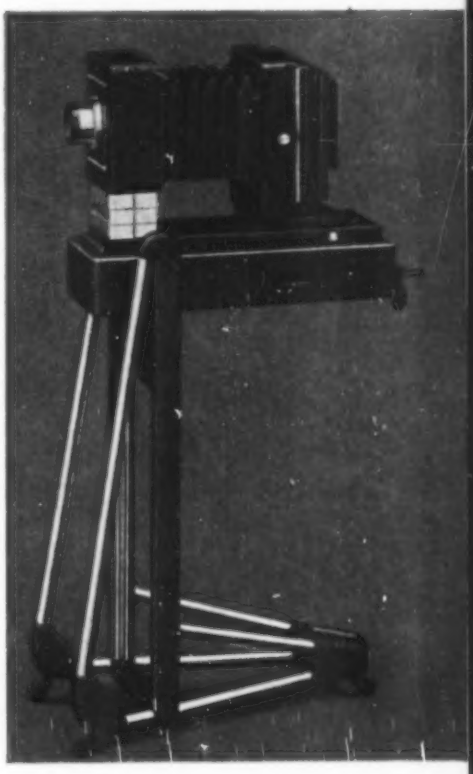
There are other advantages to the use of crayon. It is a dry medium, clean and adaptable. It permits easy overlay of one color on another to change tone. And it can be sharpened to needle-point for accuracy, and works well on guide surfaces where a brush would prove impractical.

Several makes of colored pencils are equally good: Prismacolor, Multichrome, and Dixon, for example. Materials of American manufacture are excellent and seldom is imported material used. However, Windsor-Newton tempera and brushes are used a great deal, and for fine water-color work, Whatman (English imported) board and paper is used.

Presentation Drawings. The kind of presentation to the clients depends on the product and type of job. Both models and renderings are used. While the use of renderings has been more frequent in the past, models are generally more satisfactory and their use is becoming more and more prevalent. Whatever the situation calls for in the presentation—model or rendering—it is supplemented with line drawings from which prints can be made.

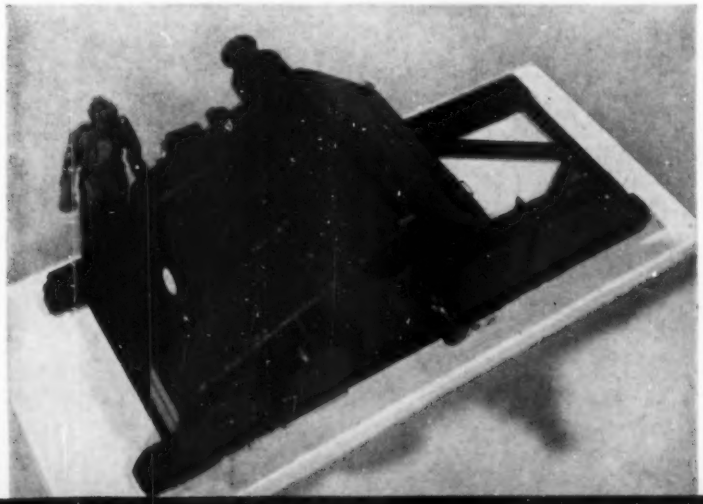
Watercolor is frequently reserved for presentation drawings. It is a less accurate and more artistic presentation than other forms, but is neverthe-

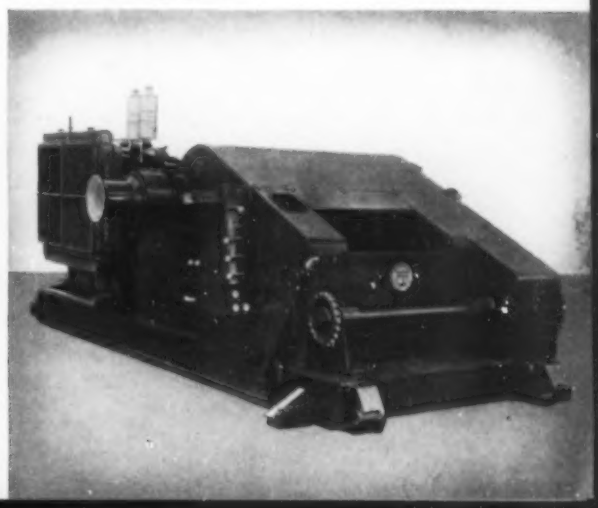
CRAYON STUDY of facet handle for the Crane Company. Note how background can be used to bring out highlights.

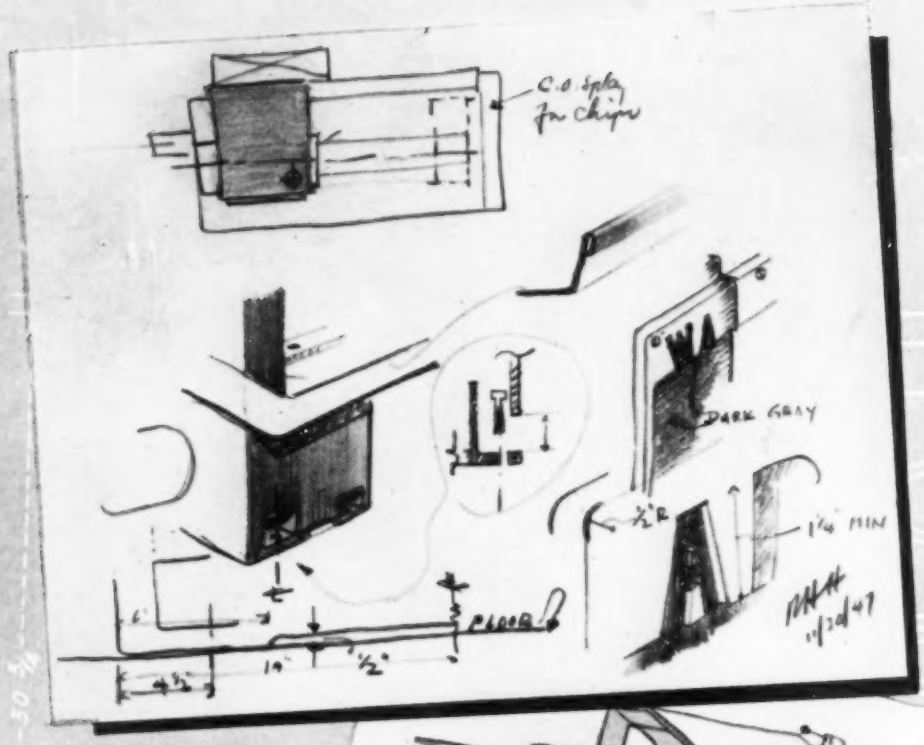


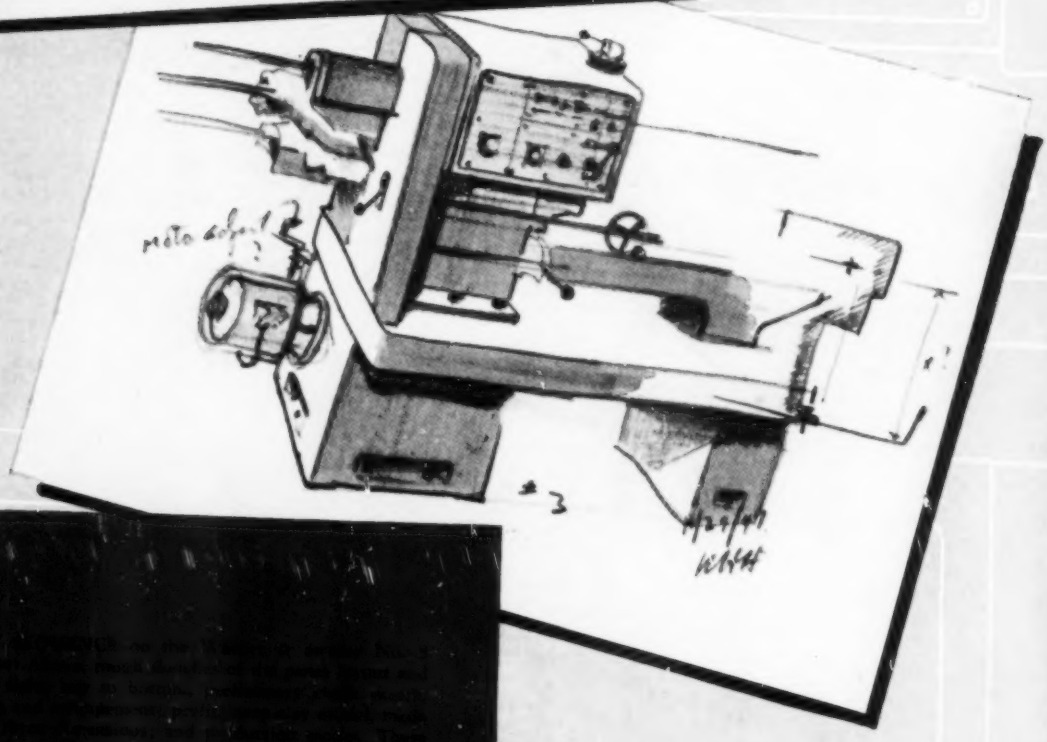
TEMPERA SKETCH. This technique is employed primarily for so called presentation drawings, as explained in text, and is preferred by many designers to over-glamourized air brush illustrations.

WOODEN MODEL, and production version of T-20 oil well drilling rig for National Supply Company. Wood is particularly useful for blocking out massive forms, and can be painted more successfully than clay or plasticene. Note almost exact duplication of detail in the final fig. Note also the use of a clay figure with the model to indicate relative size of the equipment.









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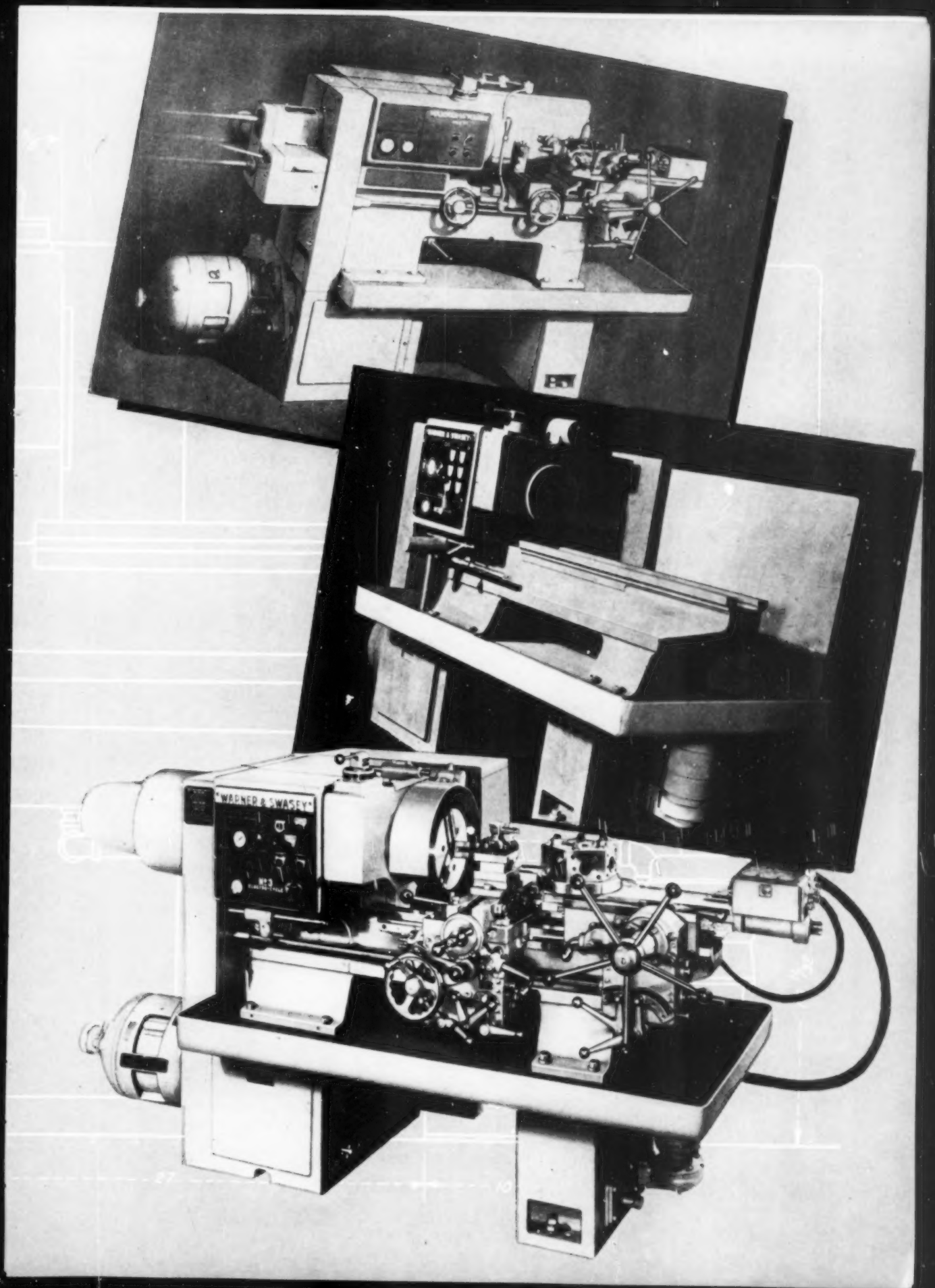
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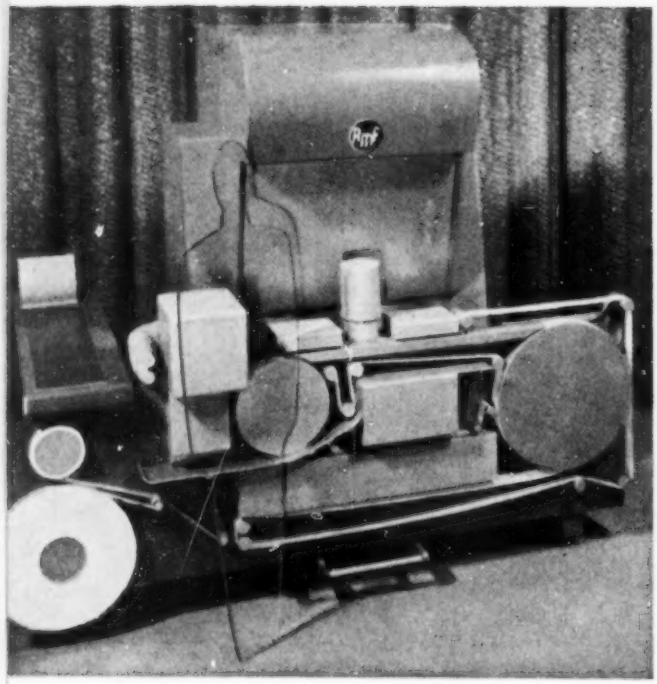
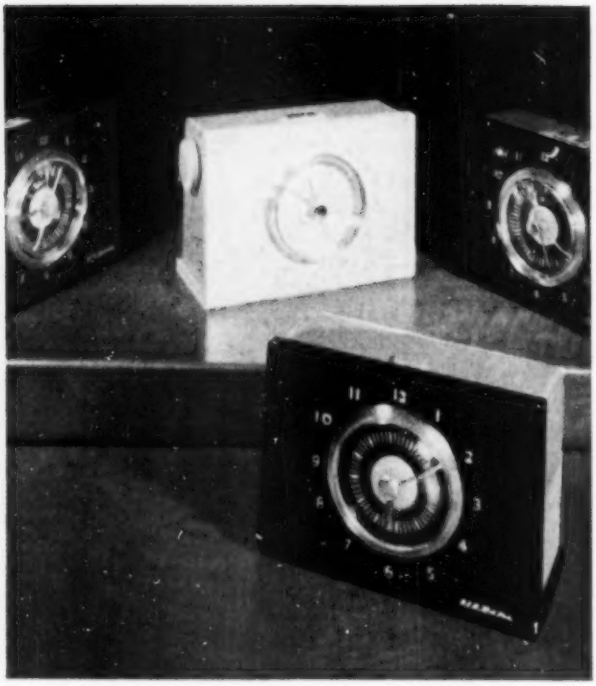


WOODEN MODEL of American Machine & Foundry cigarette machine. On equipment such as this, the initial problem is one of the proper relationship of total volumetric form, and not of detail finesse, which follows later for individual assemblies.



PRESENTATION MODEL (foreground) and production models of RCA's new executive clock radio. In this case the presentation model is made of the same materials used for production units, which is not uncommon for business and consumer products.

less preferred to air brush drawing by many industrial designers. "Smootch" is another form of drawing that is useful in blocking out mass forms. Done with powered pastels utilizing a cotton swab or the finger, it results in smooth tones somewhat similar to those obtained with air brush equipment. A finer medium, such as ink or pencil, can be used to bring out the drawing details.

Some concerns use air brush drawings when studying the contours of a new or redesigned product. Other designers feel that such presentations are slick, tricky, and not sufficiently definitive and realistic. Their contention is that the air brush technique produces a pretty picture, but not always a true and accurate one.

The important point with a presentation drawing is that it has to be sufficiently "loose" to convey an interesting picture of the acutal product, yet sufficiently tight (in detail) that it will not lead the engineering department astray.

For these reasons, many presentation renderings actually are colored drawings prepared with colored pencils on neutral background drawing board or cover paper which has sufficient "tooth" to pick up the pencil impressions and blend them to designer's satisfaction. These renderings are not sharp in detail but tend to be sufficiently "soft" to give the overall character and impression of the design. Relatively small details are often omitted entirely.

In all phases of sketching and drawing, the scale as well as the relative proportion of the drawing and the sheet are important in projecting the proper "feel" of the product to the engineer. Small objects should be drawn full size—large objects, $\frac{1}{4}$ to $\frac{1}{2}$ size. However, it is possible to make a small object seem large by using most of the drawing sheet to portray it; conversely, a large object may appear small if only a fraction of the paper is used in the presentation. There is no rule of thumb that can be followed. The size and proportion of each drawing must, in the final analysis, be based on the character of the product.

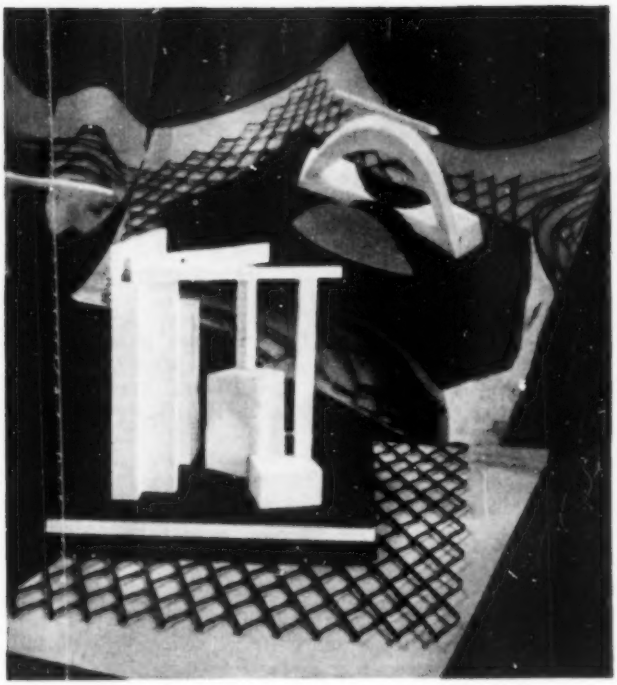
Working Drawings. The pencils used for drawings necessarily vary with the nature and size of the object. For detail work, particularly on final design work, *HB* or *F* pencils are the softest used. For blocking mass forms, a soft *3B* Eagle drafting pencil, or charcoal or graphite can be used. The disadvantage of charcoal is that it tends to pulverize and become messy. Colored pencils do all that charcoal can do and in addition to offering color instead of shading alone, work much better than charcoal on a variety of surfaces; they also permit more detailed work.

In many cases, it is advantageous to place perspective sketches in one corner of the sheet of a working drawing —to illustrate the relation of one part to another or to the whole. Usually these are single line sketches though as occasion demands they are shaded.

If the working drawings have conveyed to the maker of the production sample or prototype all the thinking and study necessary to arrive the designer's solution, they have admirably served the design purpose. A clear, well composed drawing is highly desirable but never at the expense of vital information. The best designers hold that an "over-noted" drawing is better insurance for complete and correct results than a beautiful sheet.

Scale and Full Size Models

One of the most important tools the designer can use is a fractional or full scale model. These models need not be complete in the sense of including mechanisms but must be illustrative of the overall design concept, form arrangement, and detail finesse. Such models are constructed to be a three dimensional verification of the designers thinking and are presented in a manner easily interpreted by the technical mind of the engineer and the merchandising mind of the Sales Manager. The use of preliminary rough and scale models as well as finished final models has proven to be of great value in drawing to the attention of



A TECHNIQUE developed at the School of Industrial Design, Philadelphia Museum of Art, requires students to work in plaster before a distorted parabolic stainless steel reflector. Image distortions provide the key to improved symmetry and balance.

CORDLESS SWITCHBOARD for Bell Telephone Laboratories. This is an actual working model which was made to allow engineering manufacturing, and methods and assembly studies as well as to analyze operation, form, and overall appearance.

manufacturing personnel possible cost savings in production as well as product improvement through revised engineering thinking.

The use of scale models falls generally into two basic categories: (a) Full-scale, where the product is of a "reasonable" size, such as a clock, a vacuum cleaner, a telephone; and (b) Fractional-scale, where the object is too large for convenient life-size handling, such as turret lathes or cigarette-making machines.

Usually the fractional scale is one-quarter because of habit and convenience. Most, or at least a great many, engineering groups have used quarter-scale for so long it is almost standard practice, and the interpretation of "scale" tends to become automatic.

Any number of substances can be used to make models, but clay is perhaps the most common material used by the industrial designer. There are two basic types of modeling clay; (a) natural clay, which is used primarily for monumental or heroic figures, and (b) plasticene or plastilcene, which are compositions (made with a natural clay base to which fats and oils have been added) used primarily because of permanent malleability.

The sequence of the progress of a model from rough to final form varies with the job at hand. Where form is of primary importance, the clay model is used so that changes can be made directly in the clay, thus permitting the designer to "play" with the form and see visually what his ideas will look like in three-dimensions.

Contrary to opinion, not all of the model is clay or plasticene. The basic form may be a block of wood or a frame work of wood and wire. These forms can easily be built-up or manipulated, and clay can readily be hung on them.

Clay or plasticene is used where the product is to be looked at to check form, and where little or no handling is to be required. Disadvantages are that these materials are easily damaged, their surface texture is irregular, and they cannot readily be colored or painted. Nevertheless, in those cases where the form and proportions of the model seem right but where there may be a slight conflict with function, the clay models are sometimes used for "minor" presentations to illustrate how the end product might be bettered through some minor change in function or manufacture.

In any case, the clay model period is a vital one. This phase often indicates the importance of further integration of the engineering function with the mass and many times suggests the final solution to design-engineering groups. It sometimes determines the entire design solution for products of great mass and bulk. For the smaller items, the over-the-counter purchased products, it is generally only the answer on "form" and is incomplete as to proportion related to color and texture.

The subtleties of finish and texture can so influence proportion as to make an additional sketch-model step necessary. By casting the clay model in plaster, color and texture contrasts can be applied. Through the use of plaster models, the designer can, in a relatively short time, thoroughly investigate form and proportion, the influence of color and texture on them, and develop other ideas on detail finesse.

In a great many cases, wood and metal are preferable to clay or plaster. In those instances where the form or shape is "spun" or "turned", wood or metal is preferable. Generally, clay or plaster is indicated where there is not a high degree of certainty about the exact contours or where experimentation is required. Other materials also can be used, as for example, glass or plastic, when transparency is required.

Where the model indicates a study of space (e.g. airplane interiors, railroad trains, hotel rooms,) the architectural coordination of small details is very important and the models are prepared at $\frac{1}{8}$ or $\frac{1}{4}$ size.

Several techniques and materials are used: e.g. cardboard or wood for sidewall structures, lucite for transparent areas, fabrics for carpeting and cur-

tains, and cast metal or wood models for repetitive items such as furniture.

Dimensions are taken from models in whichever of several ways assures greatest fidelity in translating actual dimensions to paper. Models can be sliced for progressive contours and three-view dimensions can be measured with any accurate system.

There are two systems in general use for the measurement of models. Where clay models are used, it is sometimes desirable to slice the model to obtain a contour from which a template may be made. The more prevalent system, however, is the "table gauge", a device which rests on a flat, level surface and which has an adjustable pin, used to "point" the model in a manner similar to that of the pantograph. All horizontal points are taken from the floor up; all vertical points are established by measuring in from the sides.

If the model is actual size, the transposition of dimensional data is relatively routine. More care, of course, must be exercised if the model is, say, one-third. The magnification of scale is not necessarily just a mathematical blow-up. Minute things on the small-scale model can become serious problems at full scale. The highlight, for example, which accentuates a contoured form on the scale model can be entirely too prominent at the larger scale. Experience and training are the only effective aids in finding solutions to this sort of problem, unless the designer wants to work only in full-scale. On such problems as passenger-liners, for instance, this full scale method is just short of insanity both on the basis of cost and time.

Whenever possible product details are studied in full size. The model of a control wheel on a turret-lathe, the hand grip area of a telephone, for example, must always be studied full scale because they relate so directly to the anatomy of the user. The models must be made of material that permits handling for the study of feel or "fit".

When study models of any scale are refined for presentation, the finesse and detail are carefully executed. Considerable thought and attention is given to the exact color, the correct texture, accurate form and dimension—so that the presentation model will accurately reflect the design and be readily understood by non-technical executive personnel.

Working or Reproduction Models

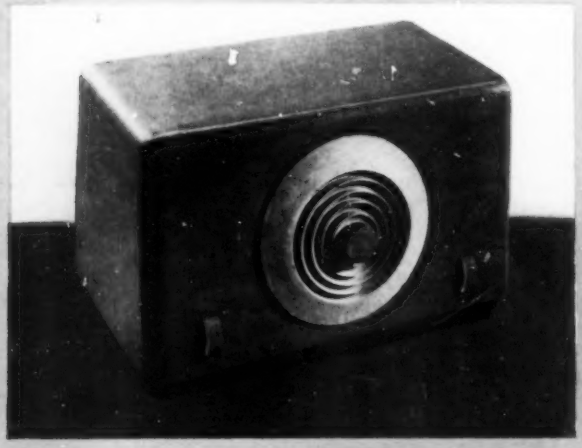
The final stage in a design, prior to tooling, usually is the working or pre-production model. Although ordinarily used for a final check on the engineering drawings, these also are useful for try-outs by customers or for a check on buying preference. This last step is carried out by merchandising personnel or the industrial designer, and is one in which there are many pitfalls. Using a working model, however, is much safer than relying on a plaster or wooden model.

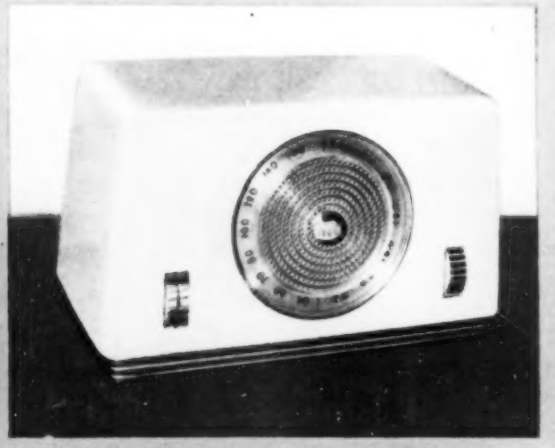
Not long ago an appliance manufacturer decided to run a test at one of the largest department stores in the country. He put a number of plaster models of his product on display and invited the store's customers to choose the appliance they preferred.

The test resulted in appliance "*A*" being overwhelmingly "preferred" by the public. Thereupon the manufacturer went into full-scale production. However, something happened between the time of the "public preference test" and the placing of the finished product on the sales counters, and the public didn't buy finished appliance *A*. Maybe it was the surface appearance of the finished product (as opposed to the surface appearance of the plaster model) that changed the "preference". It might have been a method of manufacture, cost, or the functioning of a given part that was not revealed in the model. In any case, the test was a costly failure and another warning to the designer that public opinion polls on appearance only, can be no guarantee of sales.

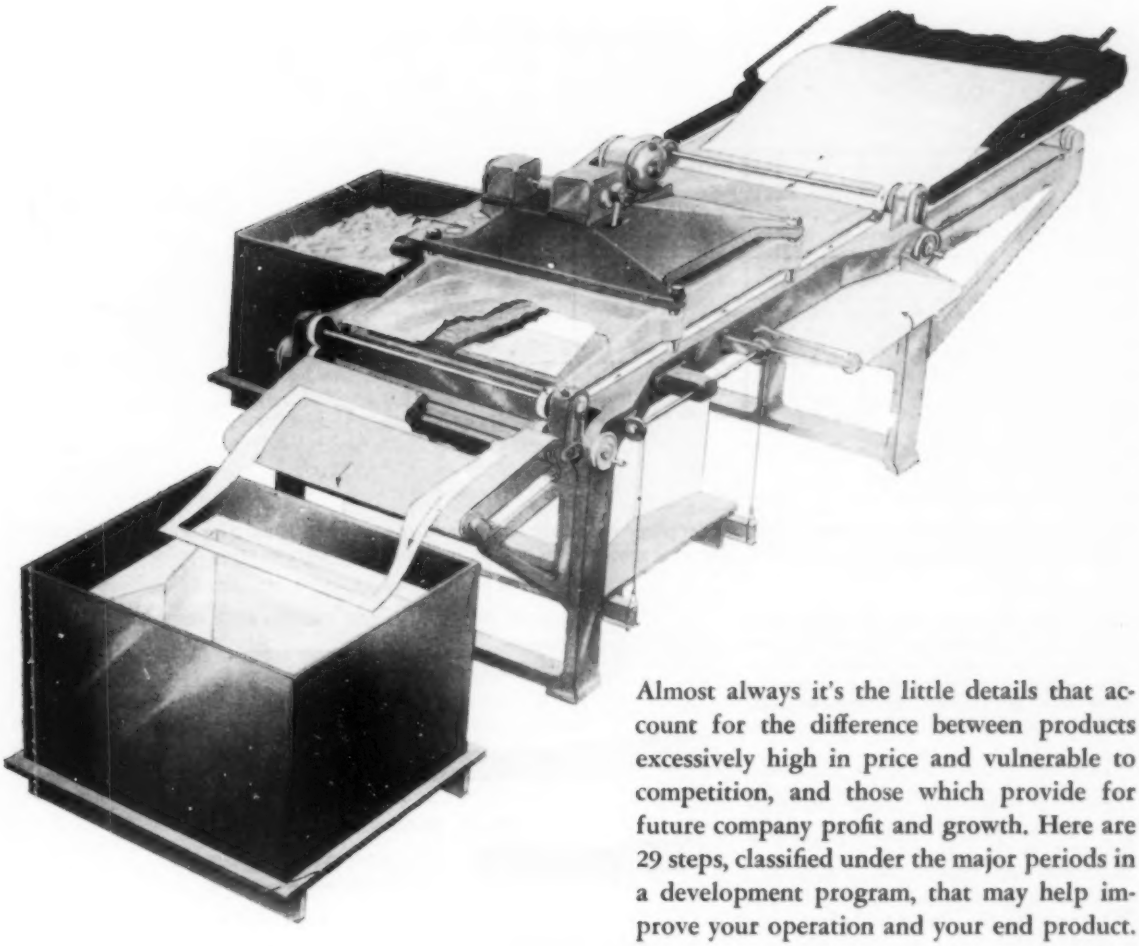
It must be constantly borne in mind by the designer that the objective being worked on is going to be sat upon, ridden in, looked at, talked into, activated, operated, or other-wise used by an individual or a group of individuals.If the point of contact between the product and the person causes friction, then the engineer and industrial designer have failed; if people are made safer, more comfortable, more efficient and happier by contact with the product, then they have succeeded.

The techniques described in this article are merely the tools of the designer, and it is up to him to choose the one which will best depict the product not only to himself, but to the management, advertising, and sales force of his client.





CLAY AND FINAL PRESENTATION models of an RCA table model radio. Rather than use clay or plasticene for the entire model, most designers utilize either a wooden block or a wire form, and build onto this the final form in plasticene.



Almost always it's the little details that account for the difference between products excessively high in price and vulnerable to competition, and those which provide for future company profit and growth. Here are 29 steps, classified under the major periods in a development program, that may help improve your operation and your end product.

The Fine Points in a

Product Development Program

GEORGE KENDALL
Consulting Engineer

WITH ENGINEERING AN EXACT SCIENCE, down to the finest dimensional tolerance and material alloy specification, product development programs require more careful study than ever before—even more thorough than that given to many other phases of company operations.

Almost all of the dissatisfaction with development programs today can be traced directly to a lack of understanding or appreciation by management of the steps required to assure a uniform degree of success. Analyses of these cases further discloses that from one-third to half of the important essentials are never included in the program schedules.

Four major divisions exist in any major development program, Fig. 1. First, there is the *formulation period,* in which all elements of the program should be evaluated. Second, there is the *determination period* in which all elements should be studied, checked, and tested to provide the proper specifications for the design program. Third is the *design period,* in which all creative design is reduced to tangible layouts and descriptions and finally into detailed working drawings and specifications. And fourth is the *follow through period* from engineering through shop, assembly, trial test, and trial production.

However, the attention that is devoted to progressive plans and details within each of these periods often determines the success or failure of the project, Fig. 2. Follow-

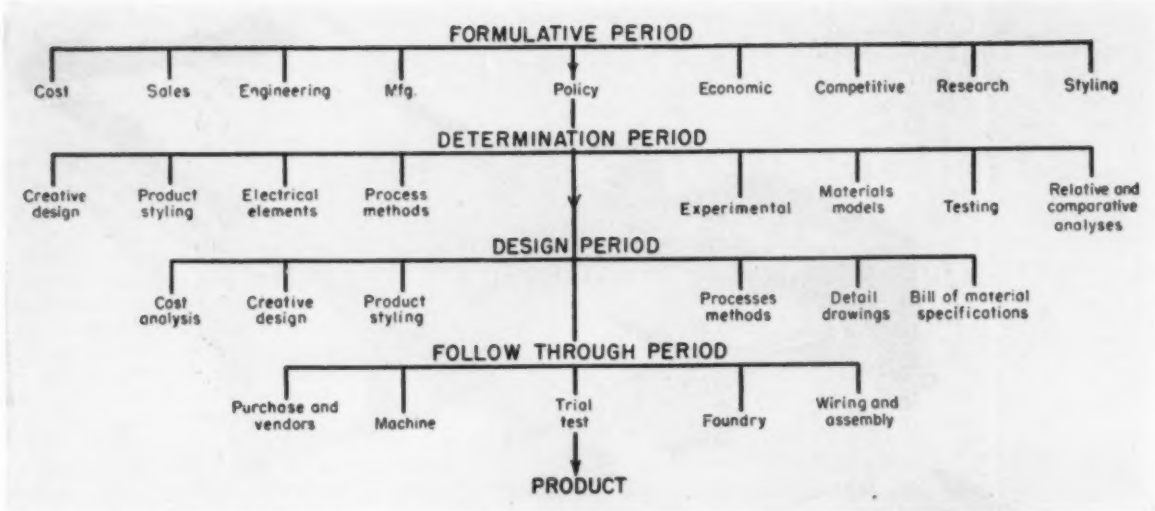
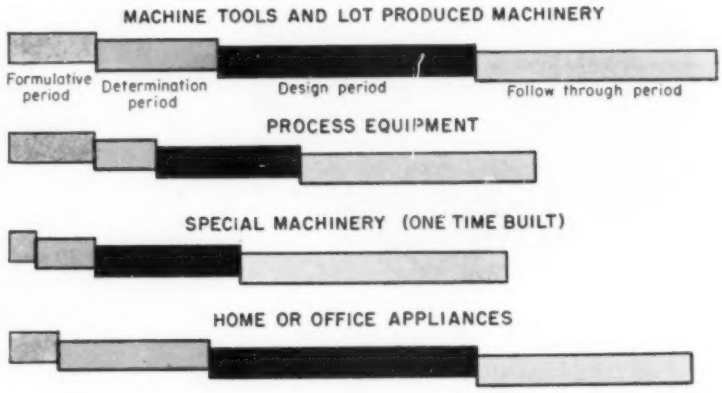


Fig. 1—Four main periods in a product development program and the scope that they encompass. Rigid scheduling plus coordination between the various engineering, production, sales, and management groups involved is necessary to avoid confusion.

Fig. 2—The amount of time allotted for each period of a development program depends on the type of equipment being designed. Adherence to an established schedule is of extreme importance in keeping development costs within estimated and reasonable limits.



ing are 29 points that bracket the entire development program and may greatly influence its final outcome.

More important than the detail under any one item is the sequence of the program. Waiting until the design period to make a fundamental policy or engineering decision is both unsound and costly.

THE FORMULATION PERIOD

This, the first phase in all programs, is the policy forming part of any project and should clearly establish what top management wants and expects from the proposed endeavor. Obtaining reference material from all sources, discussing economic factors, establishing the relative and comparative price picture, and outlining the organization and personnel set-up gives the staff a clearly defined start.

1. Of utmost importance is the establishment of objectives. This may be done by a management directive setting forth the basic scope of the particular program. As most programs arise from direct or indirect sales interest, complete sales reports should accompany the directive. These should include a description of present conditions and the need for the proposed new development.

2. Thorough sales market analysis over the entire area in which the new processes, products or machinery are to be introduced should be used to obtain broad background data on current market and competitive situations.

3. Where prior models have been commercially available over a period of years, the service records with all complaints should be made available for analysis of use, abuse, weaknesses or desirable new features or capacity limitations.

4. Separate engineering analyses of the competitive situation in cost per pound of all relative and comparative details of manufacture, including manufacturing processes and probable costs of present tools and fixtures, are of importance. And while the sales and market reports may be of excellent character it is well to have parallel field engineering spot checks of sales data to obtain the engineering viewpoint and pick up user ideas about the product.

5. The formulation period also should be used to establish the cost range desired, in view of its importance to all that follows in working through to solutions on the program. Both this and the desired weight should be ascertained whether the program calls for model redesign or

radically new approaches without prior background data. Skilled designers and process engineers can assure fairly close results to any established specification.

A wealth of material for development design reference use has been compiled with established constants that enable fairly accurate graph presentation of equipment upon a price per pound basis within any given field. (Table I and Fig. 3.) As this represents the finest skilled know-how of the best manufacturers in a given field it provides a reliable indication of the probable present costs of various sizes of equipment.

6. Closely associated with the program objectives are the basic economic questions of development cost and profit on the product. Its probable effective market life in terms of years or months influence the design and manufacturing engineering techniques to be employed. Mass production design requires decidedly different procedures from that of products for which only a few units may be produced. Large process equipment and machinery requires careful analysis of field shipping and erection problems as well as shop machining operations. The whole field of unit costs from small, medium, large and volume levels should be carefully checked against conditions that might prove non-attractive. Whether the proposed product is to be produced regularly throughout the year, or is of seasonal nature and manufactured for storage and potential market requirements, make entirely different problems for both design and manufacture.

7. Many programs today in view of their complicated nature require organizational flexibility to assure smooth cooperative procedure.

The engineering director may have a number of project engineers assigned to different problems in many phases of a large complicated business. All questions of policy, standards and procedure for smooth operation of the department can be handled by an executive committee. It is of first and vital importance that the engineering representa-

Table I—Range of Weights and Prices for Various Types of Equipment

MACHINERY	WEIGHT, LB		PRICE PER LB, $	
	Min.	Max.	Min.	Max.
Mining hoists	1,000	4,000	0.600	0.670
Steam-jacketed kettle (stainless steel throughout)	200	2,000	0.840	1.200
Steam-jacketed kettle (stainless kettle only)	200	2,000	0.710	1.050
Kneading-mixing machines (vacuum-jacketed)	5,000	35,000	0.870	1.320
Ladders, magnesium extension	30	75	1.100	1.580
Refrigeration condensing units	500	3,000	1.140	3.160
Sound motion-picture projector	25	50	11.30	16.20
Small steam turbine	100	2,500	0.710	1.630
Industrial vacuum cleaners	10	600	0.980	7.010
Small water softeners and filters	250	2,000	0.150	0.510
Large water softener and filters	30,000	110,000	0.080	0.150
Concrete mixers on skids	3,500	35,000	0.310	0.520
Outboard motors (complete)	30	200	2.780	5.130
Compressors, three-, four- and five-stage	.....	.....	.....	.....
Precision spindles	15	70	4.75	8.51
Horizontal gas engines	2,000	13,000	0.250	0.540
Vibrating-screen dust covers	250	750	0.210	0.400
Large conveyorized spray washer (wash, rinse, and hot-air dry)	4,000	8,000	0.350	0.500
Medium conveyorized spray washers (wash, rinse, and hot-air dry)	6,000	11,500	0.400	0.550
Conveyorized degreaser (wash, rinse, dry)	4,500	11,500	0.420	0.630
Hand-operated degreaser	800	3,500	0.350	0.800
Contractor's diesel locomotives	5,000	85,000	0.300	0.680
Scotch marine boilers	3,000	80,000	0.150	0.870
Steam generators	1,000	5,000	0.800	1.040
Fire tube steam boilers, horizontal, oil-fired	500	30,000	0.149	0.290
Fire tube steam boilers, vertical, oil-fired	1,500	5,000	0.190	0.290
Fire tube steam boilers, vertical, gas-fired	300	5,000	0.410	0.620
Capstans	1,000	4,000	0.360	0.600
Distribution transformers, electric	1,500	15,000	0.370	1.040
Windmill motors (including gearing)	150	5,500	0.190	0.400
Windmill towers (3-column type)	300	1,200	0.135	0.160
Windmill towers (4-column type)	300	5,000	0.120	0.190
Small air compressor, single-stage	10	175	0.550	1.940
Small air compressor, two-stage	40	600	0.640	1.600
Vertical air tanks (for small air compressors)	75	400	0.200	0.490
Hammer pulverizers (swing-hammer type)	8,000	75,000	0.300	0.430
Single roll crushers	3,000	35,000	0.250	0.480
Cutter-creaser machines, box making	6,000	30,000	0.890	1.370
Automatic cylinder printing presses, box printing	8,000	36,000	0.890	1.370
Cleaning and degreasing tanks	100	2,500	0.260	1.190
Hot-dip tanks	100	2,500	0.270	1.190
Diamond boring machines	3,000	23,000	0.550	1.140
Cone dust collectors	250	5,000	0.260	0.550
Electric rotary converter sets	40	400	1.110	2.300
Electric generator sets, gasoline-driven	75	4,000	0.750	2.450
Electric generator sets, diesel-driven	2,000	6,000	0.980	1.250
Electric magnet charger sets, gasoline-driven	1,000	3,000	0.730	1.110
Electric storage battery sets, lighting service	300	4,000	0.170	0.290

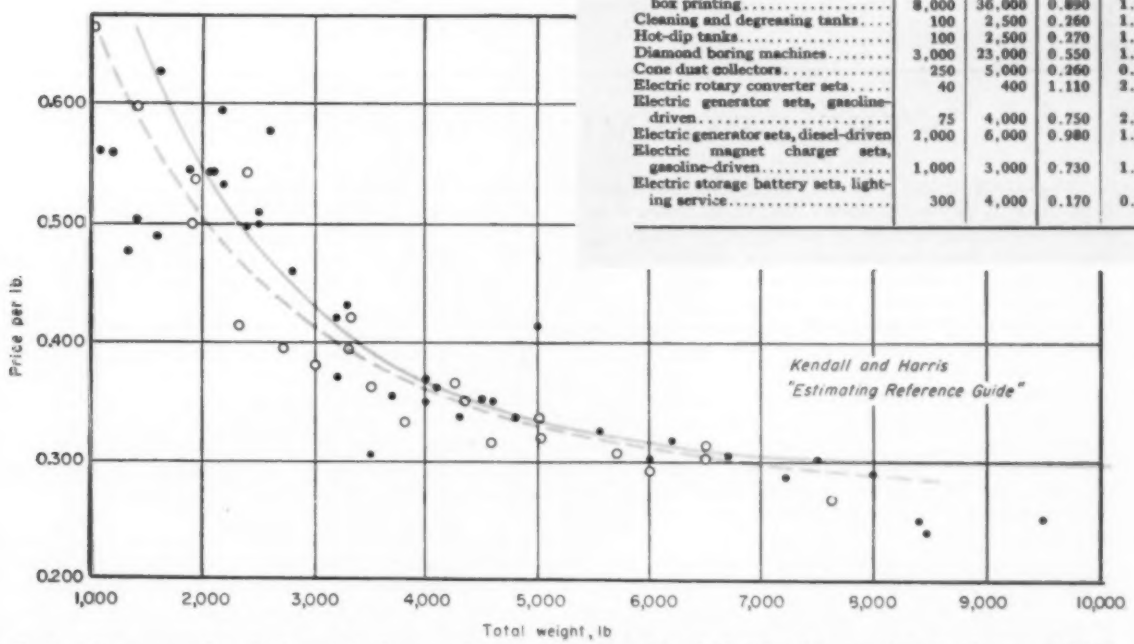


Fig. 3—Chart presentation of price per lb of two products in the metalworking field. When his price falls far above established averages any manufacturer is in trouble unless the advantage of additional features far outweighs their cost.

tives be of the highest calibre. The chairman of this group should particularly possess keen creative vision and have an impartial approach to all problems. The others preferably should represent sales engineering and manufacturing engineering to insure a small, efficient and workable committee.

8. There is a rapidly growing tendency in this country to call in the outside senior professional engineer to advise the committee and to handle such elements of the development program as may fall outside the regular scope of skills within the engineering department. See Fig. 4.

9. The importance of creative talent in trained engineers is vital to development success. It is the one trait that enables the gifted engineer to see through to simple, sound and practical solutions on about all problems to which he may be assigned. This is not the skill of the "gadgeteer" but pure, clear, straightforward thinking in planning the steps. Creative vision is not restricted or limited to college degrees; in fact the best creative thinking many times is found among those of average or minor technical training but of long years of practical experience in various fields of industry.

10. The standard forms of personnel management firms or technical employment agencies do not disclose any information whatever to enable a director to select this dividend paying quality of creative vision. Only the skilled engineer in this field of work can select those with this quality, but physiological-engineering mutual research has developed methods that conservatively give real promise of aid.

11. Probably one of the least known yet most vital factors for the success of any development department is planning for control over mental fatigue among the staff. Long years of experience have shown that if relief is not taken periodically, the average mind rapidly reaches a state of fatigue where creative vision and progress stops. If the period between relief dates is long, recovery apparently becomes equally long before effective creative thinking again fully functions.

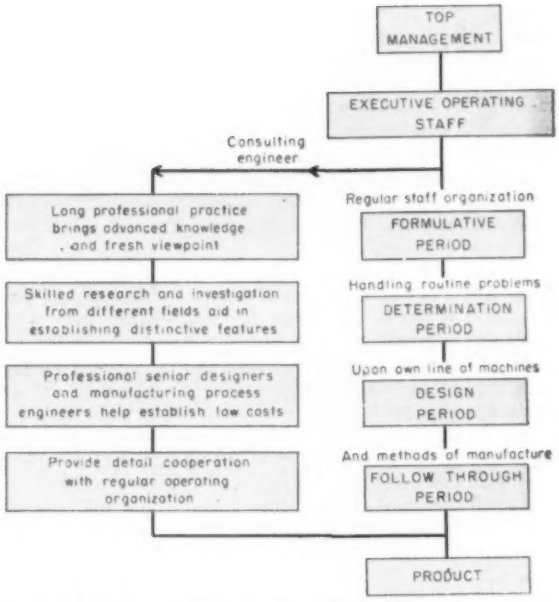

TOP MANAGEMENT
EXECUTIVE OPERATING STAFF
Consulting engineer
Regular staff organization
Long professional practice brings advanced knowledge and fresh viewpoint
FORMULATIVE PERIOD
Handling routine problems
Skilled research and investigation from different fields aid in establishing distinctive features
DETERMINATION PERIOD
Upon own line of machines
Professional senior designers and manufacturing process engineers help establish low costs
DESIGN PERIOD
And methods of manufacture
Provide detail cooperation with regular operating organization
FOLLOW THROUGH PERIOD
PRODUCT

Fig. 4—Function of the consulting engineer. Basically, advantages of employing a consultant are: (1) to obtain specialized skills not otherwise obtainable within a company; (2) to obtain a fresh outlook—one not hampered by established ideas.

Experience also has shown that development departments can greatly assist in eliminating the mental fatigue problem by assigning the development engineer to two or more problems that are carried on alternately. The net result in creative development has proved highly efficient, actually increasing the amount of work per employee. Diversification seems to greatly decrease the tendency toward creative fatigue in the majority of instances.

THE DETERMINATION PERIOD

The purpose of this phase of the development program is to establish the investigations that are to be made prior to formal design, and to set-up general design specifications. This requires decisions as to what new elements or mechanisms have been sufficiently proven by use in other fields to be handled purely as selection and specification problems. It also requires investigations of components or elements having experimental or unknown features. Examples might be the movement of linkages or feeders or the operation of servomechanisms where performance, clearance, or movement necessitates the construction of experimental models to check design.

Questions covering material properties or physical characteristics, that seem to lack sufficient supporting data to be acceptable to the program, should have the necessary laboratory checks.

12. At the start of this work, it is advisable to start a running log to record progress and patentable ideas. In later years, should any patent infringement arise this detail log takes on importance as the actual record of thoughts and actions at that time. One or two photostat copies are sometimes made and filed with patent counsel and another copy returned to the engineer's record. The original is permanently filed and in no case should it be issued or changed in any way. Should changes or corrections of errors be desirable they can be written in as amendments.

13. All design details such as operating speeds, performance characteristics, and test results on components and assemblies should be included in the daily log. Illustrative sketches also should be used to bring out details clearly. Particularly should the log include an analysis of available patents as guides upon prior art and trends within the subject classification.

14. Should the Project Engineer find that the authorized program includes wholly unknowns that should be classified as "research" this should be promptly brought to the attention of the Executive Policy Committee for further instructions that the program may not be indefinitely delayed.

Research on unknowns has no place in Scheduled Devel-

opment and Experimental Engineering Programs. The project should not have been released if the existence of unknowns were realized or if ways of getting around such a condition were not established.

Here again, the importance, of having several projects about ready for release cannot be over emphasized. In case of delay, the staff can be kept on an even work schedule and delays held to a minimum.

15. While these associated studies are underway, the initial design layouts should be developed. At this stage, outline drawings and dimensions for all purchased mechanisms and components that are to go into the proposed project should be obtained.

As the design layouts progress, complicated mechanisms may require the use of plate models or mock-ups in order to check operation and timing of linkages and gear trains, to plot the desired motions, or to ascertain tracking and clearance.

16. Depending upon the type of process, product or machine the product stylist should initially establish the basic principles of the styling that are to be specified so that the work of the design and manufacturing engineer may proceed. Where the color, finish, and contour of the product are salient factors, air brush illustrations of many combinations should be discussed and compared. (See "The Mechanics of Industrial Design" in this issue.)

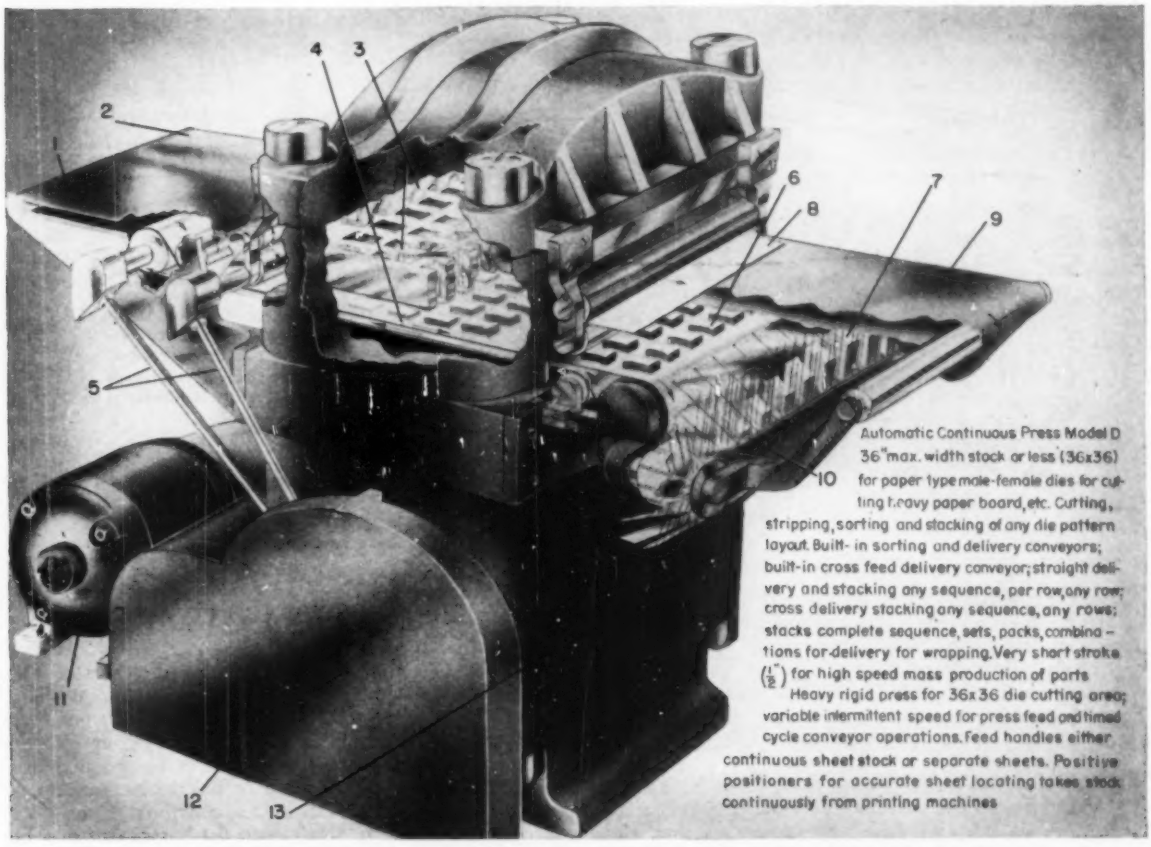
17. Manufacturing and process analysis should be carried on along with the initial design study to determine how proposed manufacturing operations might affect the design, and vice versa. For example, the lathe swing capacity of the shop might be 97 in. dia and a proposed design call for a 100 in. diameter or other dimension beyond the capacity of existing equipment. This would involve heavy capital investment for new machines, or sub-contracting for machining of the part, if process engineering studies were not brought into the program in its early stages.

The skilled process engineer, by a thorough study of manufacturing operations, may reduce their number as much as twenty to forty percent while simplifying the operations themselves. It is often here that manufacturing profit margins are made or lost.

18. Along with the other major investigations in the determination period is the basic need for defining the proper types and classes of all electrical equipment for drives and controls that the design structure may provide for them.

The relative and comparative proportion of the first design layouts necessitates having dimension sheets of the proposed electrical equipment selected for the project. Many times controllers and other devices are too large to be built into the proposed machine and require wall mounting.

Questions of whether the drives are to have a fixed speed,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Automatic Continuous Press Model D
36" max. width stock or less (36x36) for paper type male-female dies for cutting heavy paper board, etc. Cutting, stripping, sorting and stacking of any die pattern layout. Built-in sorting and delivery conveyors; built-in cross feed delivery conveyor; straight delivery and stacking any sequence, per row, any row; cross delivery stacking any sequence, any rows; stacks complete sequence, sets, packs, combinations for delivery for wrapping. Very short stroke (1/2") for high speed mass production of parts
Heavy rigid press for 36x36 die cutting area; variable intermittent speed for press feed and timed cycle conveyor operations. Feed handles either continuous sheet stock or separate sheets. Positive positioners for accurate sheet locating takes stock continuously from printing machines

Fig. 5—Presentation drawings of automatic card cutting and stacking machines prepared by the Briggs Filtration Company. Although they appear to be finished operating machines, both were in the Determination Period. The sketches represent only initial paper studies for engineering and management. Note that the illustrations provide by reference numbers, and at one side, a tabulation of the proposed new machine or process equipment features.

Fig. 6—Bill of Materials Specifications. These should be made separately, and not listed as a part of assembly or engineering part drawings.

BILL OF MATERIAL SPECIFICATIONS

GEORGE H. KENDALL
Consulting Mechanical Engineer
DARIEN, CONNECTICUT

PROJECT # 464
SHEET # 4 OF 34
SECTION # 6
Issued Sept. 1, 1952.

FIRM Marshall Manufacturing Company
ADDRESS 13642 Jefferson Boulevard, Los Angeles, California
MACHINE Continuous Cut - Takeoff - Print Process
MECHANISM Takeoff Mechanism

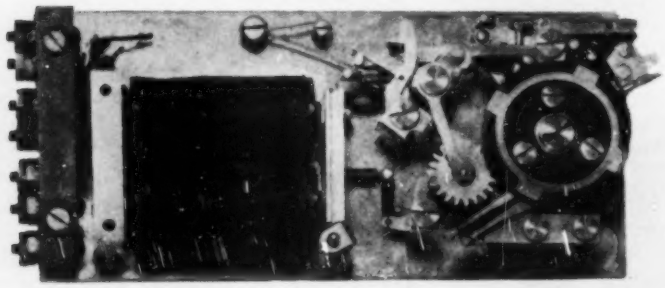
DRAWING NUMBER	NAME OF PART ON DRAWING	MATERIAL SPEC.	NO. REQ'D.	SOURCE OF SUPPLY
464-4-73-1	Exhaust Manifold	Cal.Iron	4	
464-4-73-2	Manifold Studs	C. R. S.	20	
464-4-73-3	Exhaust Manifold Gasket	Rubber	4	
464-4-73-4	End Plate	C. R. S.	8	
464-4-42-1	Large Punch (.060)	T. S.	32¼	
464-4-42-2	Small Punch (.040)	T. S.	7,52¼	
464-4-42-3	Large Punch for Slots .039 x 332	T. S.	16¼	
464-4-42-4	Small Punch for slots .039 x 227	T. S.	16¼	
464-4-66	Bushing	Steel	16	Danly 6-10-2
464-4-66	Guide Pin	"	8	Danly 5-1018-1
464-4-66	Guide Post	"	2¼	Danly 5-0414-1
464-4-66	Shoulder Bushing ⌀ = 3/4 P = 1/2 L = 1⅜	"	2¼	Danly 6-04-2
464-4-66	Socket Hd. Stripper Bolt	"	88	Danly Body ⌀ 3/8 Length = 2-1/2
464-4-66	H.P. Spring Hole ⌀ 3/4 Rod ⌀ 3/8 L = 2 1/2	"	88	Danly 9-1210-12
464-4-66	1/2 Std. Lock Washer	"	64	

NOTE: The Vender is to have the right of full substitution of materials of equivalent or better qualities based upon its current experience and to facilitate delivery on any restricted items, but is to record all such changes on these drawings and specifications and subject to written approval of engineers.

464-4-65 General Assembly
464-4-66 End View and Sections
464-4-66-2 Master Bare
464-4-66-3 Adjusting Block L. H.
464-4-66-4 Adjusting Block R. H.
464-4-66-6 Adjusting Screw
464-4-66-7 Indicator
464-4-67 Punch and Die Base Plate
464-4-68-1 Wear Plate
464-4-68-2 Stripper Plate
464-4-71 Die Backing Plate
464-4-72-1 Punch Backing Plate
464-4-72-2 Punch Holder
464-4-72-3 Die Plate

*IMPORTANT - Note the punch length specified is the short length. If alternate length punches are to be used they may be 1/16" longer for the intermediate punch and 1/8" longer for the intersection punch.

IMPORTANT VENDOR NOTE: SPECIFICATIONS ARE NOT TO BE CHANGED WITHOUT CUSTOMER APPROVAL AND THE FINAL DETAIL RECORDING ON DRAWINGS AND BILL OF MATERIAL SPECIFICATIONS.



Electro-mechanical plate model built by International Business Machines Corporation for study during one of their development programs on office equipment.

two or three selected speeds, or infinitely adjustable speeds involve entirely different equipment and controls. The same applies to other items such as the type of sequence timer control in automatic machines, infinitely variable transmissions, and combined mechanical-electrical mechanisms. For volume equipment, of course, most electrical manufacturers will prepare detail drawings to specifications.

19. It is well to remember that many times the members of management committees are not engineers and in some cases do not even have engineering training, their skills being in other fields such as administration, finance, sales, advertising, or accounting. Therefore the presentation material for any project must enable quick, clear visualization of the essential features and advantages of the program by all concerned. Failure to properly present a development may be solely responsible for its not being understood and therefore not approved by management.

Colored illustrations, such as air-brush drawings in full, sectional or phantom views, are an effective medium, Fig. 5. Small or full scale models are particularly good for such products as instruments, office equipment, appliances, and toys. Where the product involves complicated machinery composed of gear, cam or linkage mechanisms, a fine presentation often can be realized through use of a simple plate model mounted upon flat boards that may be carried about and placed upon tables for presentation.

20. When approval is given to the "Specification for Design" the rest of the program operates practically

upon a frozen status of definite established background data that assures rapid design progress free from all back-tracing for missing essentials.

Any program proceeding without these essentials being clearly established can only result in needless expense, a more expensive product than necessary, a higher manufacturing cost in tools and fixtures and the strong chance of loss of most or all of the profit. The highways of development are strewn with the wreckage of programs that can be traced directly to failure to establish a "Specification for Design" before rushing into direct design work.

The time required for these studies is nothing when compared to the years of continued manufacture and use of the proposed product.

THE DESIGN PERIOD

21. In the design period, the initial layouts together with all coordinated notes on function, structure and electrical controls, are drawn into exacting specifications for construction. Engineering on all phases of the program must be correlated. Those assigned to the mechanical, electrical, metallurgical, hydraulic, manufacturing, and styling departments must coordinate their work in scheduled sequence to permit smooth progress of the project. Process engineering, however, should follow slightly the design-engineering phases.

22. In a few weeks or months, depending on the size of the program, complete design layouts become available for final study and discussion with top management. These should be studied by top authorities in sales, manufacturing and other departments. Suggestions or comments should be made before final "freezing" of the design layouts. Any changes beyond this point are extremely costly and time consuming.

23. Formal approval should be given at this stage by all top management officials. The approved design layouts for the program should be accompanied by all data and specifications for purchased parts and components.

24. While making of the actual working drawings is considered a routine matter, it is vital to successful manufacture. Most shops have established working tolerances and standards for various components. Copies of these standards, as well as all machining and assembly instruction procedures, should be given to every detailing draftsman and engineer in the organization. It is only common sense that these facts must be kept constantly and continually before the engineers.

25. Bills of Material and Specifications, Fig. 6, are the index guides for the entire project. The tabulated list of parts on each large sheet of detail drawings (where each detail is not on a separate sheet) should never be accepted as formal specifications.

The Bill of Material Specifications should be made up separately, and preferably be placed on 8½ x 11 in. sheets for filing by all purchasing, material scheduling and planning, receiving and shop departments as well as by venders and sub-contractors. The date of issue should be on every sheet and on every print issued.

The final Bill of Material Specifications should contain a record of the quantity of every part required for the complete project, with specifications for its purchase or manufacture. All mechanisms or attachments may be listed under sub-headings for convenience of arrangement and ease of reader use and reference.

26. The checker on the project should be responsible for the accuracy of the specifications to the same degree as for the detail and assembly drawings. It is essential to realize that proper checking takes time and must be provided for in any program schedule. From five to ten percent of the entire detail drawing time of a project should be allowed for checking and scheduling.

27. When the complete drawings and Bill of Material Specifications are delivered to the Director of Engineering, a final conference is usually desirable to compare the top management authorization of the program with the final design specification.

A report of suggested follow through handling by an assigned engineer should go to top management for its study, approval and authorization.

THE FOLLOW THROUGH PERIOD

28. The program, now complete in full accordance with its authorization, returns to the formulation group or President for further decisions and construction authorization.

It is well at this stage of development to call upon all initial creative departments and individuals to review their material, to advise of any later trends that may have come to their attention in performance of their work, and to suggest final modifications to simplify manufacture.

29. When initial construction of trial machines or production lots are authorized for manufacture the activities and follow through schedules of the engineers engaged in production should be established.

Initial construction of any new machine or product raises many questions on just how designs are to be interpreted, and on the sequence of assembly operations essential to secure ideal results. This continues from the first conference discussions right through the many weeks of material ordering, pattern making, machining, assembly, and trial operation. Questions also arise on changes that can be made to expedite delivery with the purchasing and vender representatives.

Follow through by a design project engineer is essential to assure the continued smooth handling of the specifications, particularly when subcontractors are to build the first trial machines. Failure to provide for design engineering guidance in the shop invariably results in different shop opinions, from lack of designer knowledge, and in changes that effect design, accuracy and purpose as well as cost. Normally, such an assignment involves only a few hours a week away from other engineering duties.

Influence of on Brittle

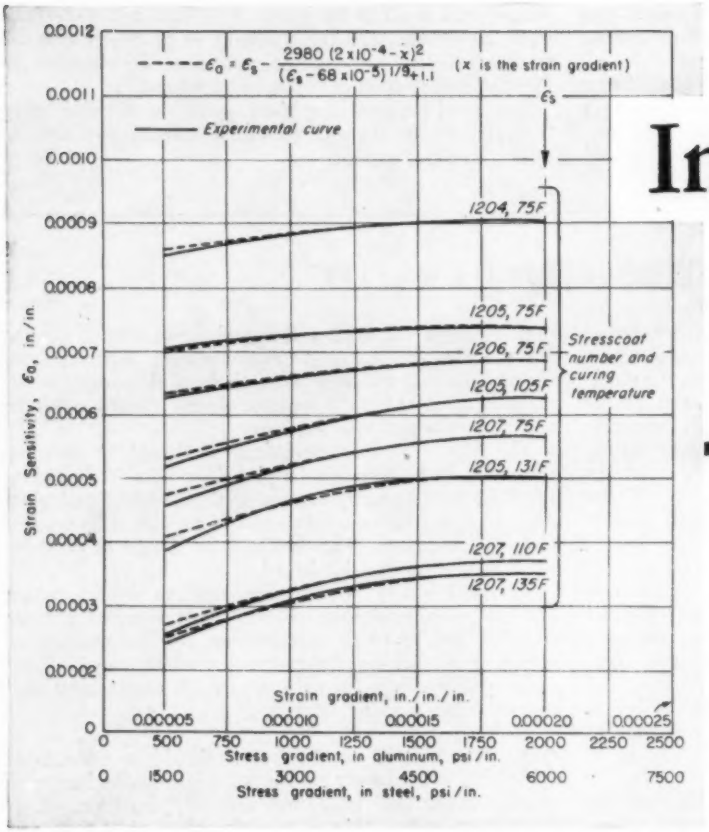


Fig. 1—Influence of strain gradient normal to cracks on the strain sensitivity of Stresscoat in a unidirectional state of stress. Strain sensitivities were determined at 75 F and 40 percent relative humidity. Solid lines are test results.

A. J. DURELLI
S. OKUBO
Armour Research Foundation

ANALYSIS OF STRESSES in machine parts and structural components of complicated shape by the brittle coating method is now a common procedure in many laboratories. Interpretation of the results is simple when based on the assumption that the coating breaks at the moment the material underneath reaches a characteristic value of tensile stress. Most brittle coating test results are evaluated on this basis. Failure is a complex phenomenon, however, governed by many variables. Among these the rate of loading, the time of maximum load duration, biaxiality, stress gradients, and the area under a particular stress gradient are the most important.

In an extensive paper, "Study of Some Properties of Stresscoat", Society for Experimental Stress Analysis, Fall 1950, the authors studied the influence of several of these variables with the purpose of increasing the accuracy of the coating determinations. This article deals with some new developments in the study of the influence of the strain gradient perpendicular to the crack on the failure of the coating. This new knowledge makes it possible to improve the interpretation of the results obtained by stress analysis.

The tests here reported were conducted with Stresscoat and the standard calibrating beam provided by Magnaflux Corporation. The standard calibrating beam is a strip 1 × 12 × ¼ in.; it is loaded as a cantilever by an eccentric wheel to a deflection of 0.592 in. This loading produces a unidirectional state of stress on the surface of the strip. The longitudinal strain at any point on the surface of the strip is determined with a graduated scale. The strain gradient produced by this loading is 0.0002 (in./in.)/in., which corresponds to a stress gradient of 2,000 psi/in. in aluminum and 6,000 psi/in. in steel.

To study the influence of strain gradient on the strain sensitivity of the coating, it was desirable to be able to change conveniently the strain gradient of the standard calibrating beam. For this purpose, three additional holes were machined into the eccentric loading wheel. These holes were placed so as to give deflections of ¼, ⅓, ½, of the full 0.592 in. deflection, or the respective fractional parts of a 0.0002 (in./in.)/in. strain gradient.

Coatings No. 1204 through 1207 were used to study the influence of the strain gradient perpendicular to the crack on the coating strain sensitivity. Curing temperatures were chosen to provide a series of curves of strain sensitivities from approximately 90 × 10^{-5} to 35 × 10^{-5} at full deflection; this range is a practical one for static tests.

Test procedure consisted of the following steps: Spraying as many as 10 to 20 calibration strips, curing the coating at the desired temperature and slowly cooling the coating to room temperature, cracking the strips at the smallest possible strain gradient, and recracking the strips with increasing strain gradient to the final full deflection.

A time interval of at least 12 times the time required to load and unload the strip was maintained between loadings, which is more than necessary to avoid the possibility of the effect of creep on the strain sensitivity. Tests were made to prove that previous loading of the same strip had no influence on the results.

The results of these tests are shown by the family of solid curves shown in Fig. 1. These curves represent the average of all the tests conducted.

Where

x = strain gradient at the investigated point, (in./in.)/in.

Strain Gradient Coating Sensitivity

Fig. 2—Brittle coating stress analysis of a steel valve body that was tested under internal pressure. Numerals on isoenatics give the corresponding pressure in tens of pounds per square inch. The maximum principal stress at point B computed by the conventional method is 16 percent greater than the stress corrected for gradient influence.

ϵ_s = strain sensitivity of the coating when the strain gradient is 0.0002 (in./in.)/in.

ϵ_a = corrected strain sensitivity when the strain gradient is x

The dash-line curves in Fig. 1 are plotted from values obtained from the approximate formula.

$$\epsilon_s = \epsilon_a - \frac{2980\,(2 \times 10^{-4} - x)^3}{(\epsilon_a - 68 \times 10^{-6})^{1/9} + 1.1}$$

These curves show that the influence of strain gradient is appreciable for the low strain sensitivity coatings and that this influence gradually decreases as the strain sensitivity increases.

For example, the bottom curve of Fig. 1 indicates for that coating that at a strain gradient of 0.00005 (in./in.)/in. the strain sensitivity is about 31 percent less than at a strain gradient of 0.0002 (in./in.)/in. These data mean that about 31 percent less strain gradient is required to crack that coating on aluminum in which the stress gradient is 500 psi/in. than is required to crack that coating at a stress gradient of 2,000 psi/inch.

Other characteristic curves within the range of strain sensitivities given in Fig. 1 can be interpolated by following the general shape of the nearest upper and lower curves, or they can be computed using the approximate formula given for the dash-line curves.

The following example demonstrates the practical application of this new information to a brittle coating stress analysis of the steel valve body tested under internal pressure shown in Fig. 2. The thin lines (isostatics) are cracks in the coating. The heavy lines (isoentatics) connect the crack ends obtained after each load increment. The numerals on the isoentatics give the corresponding pressure in tens of pounds per square inch.

In this example the assumptions, test conditions, and results are:

1. Coating strain sensitivity is 50×10^{-5}
2. No cracks appeared until the internal pressure exceeded 55 psi
3. Internal pressure of 60 psi is the standard load. For any other pressure, the ratio of stresses at that pressure to those caused by the standard load is directly proportional to the ratio of the pressure.
4. Distance from A to B is 0.5 inch
5. Distance from B to C is 0.75 inch
6. Distance from C to D is 0.75 inch.

Calculation of Stresses Neglecting Stress Gradient Effects.

Stress S_b at point B on isoentatic 6 when the internal pressure is 60 psi, is

$$S_B = 50 \times 10^{-6} \times 30 \times 10^6 = 15{,}000 \text{ psi}$$

Since no cracks appeared at A at a pressure of 55 psi, the stress S_A at point A over the pressure interval from 55 to 60 psi is

$$(60/55) \times 15{,}000 \text{ psi} > S_A > 15{,}000 \text{ psi}$$

or

$$16{,}400 \text{ psi} > S_A > 15{,}000 \text{ psi}$$

$$S_A = \frac{16{,}400 + 15{,}000}{2}$$

$$= 15{,}700 \text{ psi, approximately}$$

Stress at point D at a pressure of 60 psi is

$$S_D = (6/8) \times 15{,}000 = 11{,}300 \text{ psi}$$

therefore, the approximate stress at C at a pressure of 60 psi is

$$S_C = \frac{S_B + S_D}{2} = \frac{15{,}000 + 11{,}300}{2}$$

$$= 13{,}100 \text{ psi}$$

Since the distance between A and C is 1.25 in., the average stress gradient G_{AC} at an internal pressure of 60 psi is

$$G_{AC} = \frac{15{,}700 - 13{,}100}{1.25} = 2{,}080 \text{ psi/in.}$$

Correction for Stress Gradient Effect.

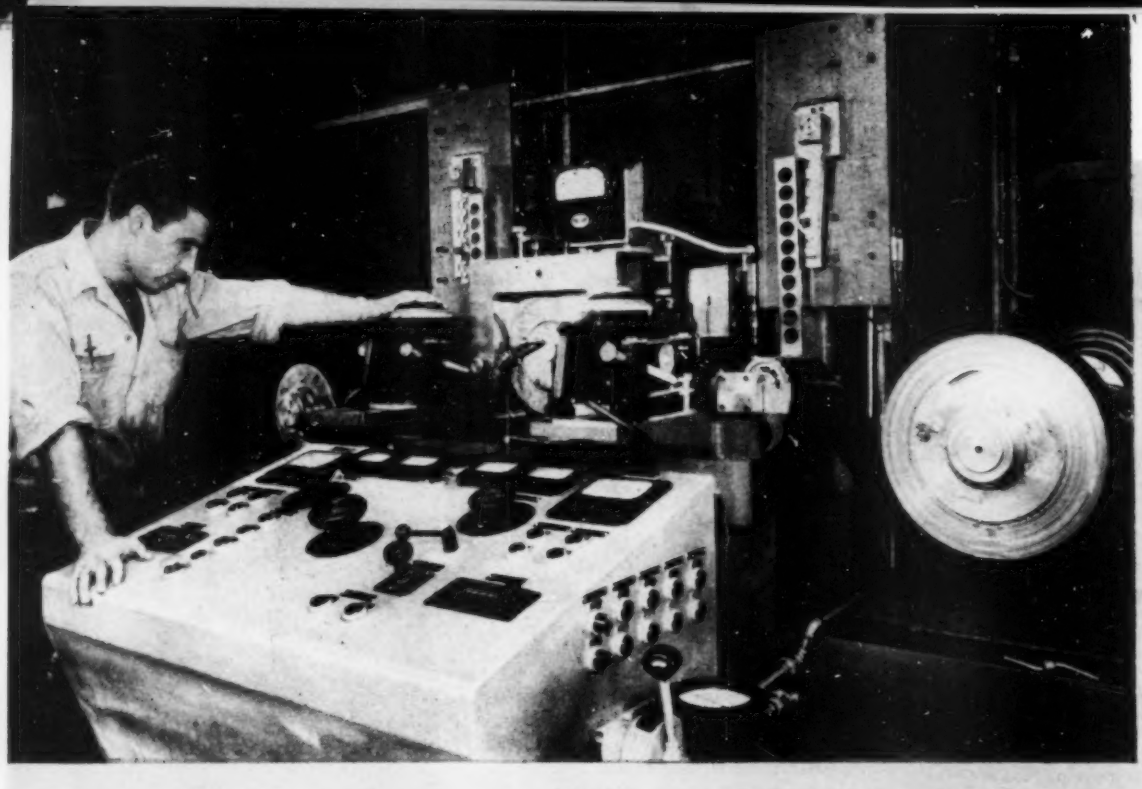
The curve in Fig. 1 corresponding to an ϵ_s of 0.0005 at 6,000 psi/in. in steel gives for a stress gradient of 2,080 psi/in. a corresponding strain sensitivity of 0.00042. Using this value, the corrected stress at B at the internal pressure of 60 psi is

$$\sigma_B = 42 \times 10^{-6} \times 30 \times 10^6 = 12{,}600 \text{ psi}$$

or about 16 percent less than the uncorrected stress.

Since point A is at the bottom of a valley of stresses, the gradient will be zero at that point.

Although at present no information is available on the change in strain sensitivity produced by gradients lower than 1500 psi/in. in steel, it is safe to assume that the correction in the maximum possible stress at A will be at least as large as at B. The stresses at other points can be corrected in similar manner.



PRODUCTION OF THIN METAL STRIP

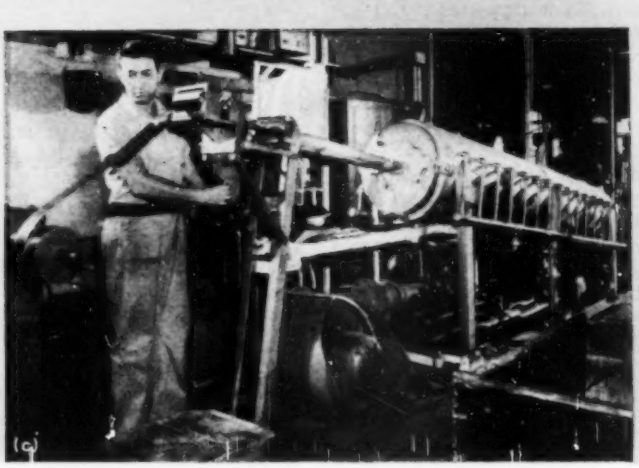
(a) Metal bars 1½ in. thick, in mill lengths are rolled down to 0.075 in. thick "snakes."

(b) On this 2-high mill the long "snake" is rolled down to a rough coil of metal, about 0.020 in. thick and then on a 4-high mill to 0.002 inches.

(c) Rolled strip is annealed in continuous atmosphere furnaces. This annealing strip may occur during any stage of the rolling process or after precision rolling on the Sendzimir mill.

(d) Precision slitting can be done rapidly to tolerances as close as ±0.001 in. in widths from 0.125 to 9 inches.

(e) On the Sendzimir mill, which uses work rolls less than ½ in. in dia, 0.002 in. strip from the 4-high mill can be rolled to 0.0005 in. with tolerances as close as ±0.0001 in.



Paper-Thin Metals—

MONROE SHERMAN
President, American Silver Co.

THE EMPHASIS on miniaturization of components in the electronic, aviation, instrumentation and allied industries has created a need for metal strip rolled to thin gages and to high precision tolerances. The development of new forming techniques has increased the availability of these materials and thus added impetus to design with thin metals. A wide variety of metal strip can now be rolled to thicknesses down to 0.0005 in. and to tolerances as close as ±0.0001 inches.

Metals now processed in close tolerances thin gage strip include:

1. Aluminum alloys
2. Copper base alloys—brass, bronze, beryllium copper, phosphor bronze, nickel silver.
3. Ferrous metals—low and high carbon steels; stainless steels; chrome-iron alloys; nickel-iron alloys; chrome-molybdenum-iron alloys; cobalt-nickel-iron alloys.
4. Nickel-base alloys—nickel, monel, Inconel, high nickel permanent magnet alloys.
5. High temperature alloys
6. Molybdenum, tantalum, titanium, zirconium
7. Precious metals

These metals are produced in widths up to eight inches and in thick-

Fig. 1—(Left) This Sendzimir mill is used to roll a wide variety of metals for the electronics, aviation and instrumentation industries.

Fig. 2

Availability Stimulates Design

nesses down to 0.0005 inches. Generally gage tolerances as close as ± 0.0002 in. are held on thicknesses from 0.010 in. to 0.006 in.; tolerances as close as ±0.0001 in. are held on thicknesses below 0.006 inches.

There have been two major bottlenecks to the availability of this thin metal-strip—(a) the smallness of the quantities required and (b) the lack of equipment to roll the very thin and the close tolerance gages.

As an example of the quantity problem, to make 100,000 diaphragms for an electronic instrument requires only about 50 pounds of metal. Such a quantity especially if required in a short time, would usually be refused by commercial mills. Even if the existing equipment could roll the metal to the required size the order would not warrant the inconvenience of interrupting normal schedules to set up the machinery.

ROLLING TECHNIQUES

Rolling techniques were borrowed from the jewelry industry to overcome the limitations of commercial rolling equipment. The units comprising the setup for producing thin metal strip include 2-high and 4-high precision rolling mills, a Sendzimir mill, precision gang slitters and continuous atmosphere annealing furnaces.

The Sendzimir mill, Fig. 1, is the

key to the success of the operation. This machine has the advantages of high speed, good accuracy and uniformity and ease of changing rolls to accommodate different metals and to alter the gage.

The Sendzimer mill has been adapted to accommodate a wide range of metals by using twenty horsepower motors on both the mill and winder drives. These large motors allow heavy passes at high speeds on such hard-to-work metals as stainless steel, high nickel magnetic alloys, Inconel and beryllium copper.

Strip stock from three inches to eight inches wide can be handled. The only adjustment needed for changing the width is the selection and installation of the appropriate drive roll on the mill.

The speed range of the mill is infinitely variable by manual control from zero to 300 feet per minute. Acceleration and deceleration are controlled by the mill operator.

Strip tension is maintained at any value between 100 and 3,000 lb by a tensiometer. This consists of a mechanical linkage with a "billy" roll over which the strip passes, and a compressed air cylinder unit that balances the movement of the linkage. The desired tension is set by varying the linkage ratio and varying the air pressure over a range from zero to 80 psi. The winder motor torque is controlled by an electronic variable speed unit that receives its signals from a reactor with an iron core moving in relation to the tensiometer linkage arm. The tensiometer system can be set so that no "hunting" is experienced over the field range of tensions, coil build-up and mill speeds obtainable.

The strip thickness is controlled by "magnetic" flying micrometers that are moved by the operator across the width of the strip as he reduces the metal. The gages are kept in constant contact with the strip providing practically 100 percent inspection of the stock. The indicating instruments are calibrated in 0.0001 in. divisions, allowing for easy reading down to 0.00005 inches.

The mill work rolls and drive rolls, Fig.. 2 (e), are easily and quickly changed because no conventional bearings are used; the rolls simply rest in the cluster formed by the surrounding back-up bearings. Because of the smallness of the work rolls (less than ½ inch in diameter) very heavy reductions can be taken without the need for intermediate anneals. Table I shows a typical reduction schedule for Type 302 stainless steel. The intermediate anneals can only be omitted however when the strip is required with a hard temper. If either soft or half hard tempers are required the metal is taken off the mill at the appropriate point, annealed, and then given a final temper pass, either on the Sendzimir mill or on a 2-high or 4-high mill. On the whole the Sendzimir mill is best suited for processing work to at least a full hard temper (40 percent minimum reduction) and does not generally prove economical on the slight reductions that are required for the lower tempers.

Table I—Reduction Schedule

Type 302 Stainless Steel, Annealed at 0.008 in.

Pass	Thickness, in.	Percent Reduction
0	0.0080	
1	0.0050	37.5
2	0.0040	20.0
3	0.0030	25.0
4	0.0026	13.3
5	0.0022	15.4
6	0.0018	18.2
7	0.0014	22.2
8	0.0012	14.3
9	0.0010	16.7

Uses for Paper-Thin Metals

Currently the major uses for very thin metal strips are in the instrumentation, electronics and aircraft industries. Pressure vessel bursting disks, diaphragms and magnetic cores are typical examples.

One recent development has been the construction of small, thin gage cores for high frequency magnetic amplifiers or "flip-flop" magnetic components in computer applications. In the latter application circuit development had reached the point where there was no available magnetic material thin enough to reverse its magnetism with the required rapidity. Satisfactory results are now obtained with 3 percent silicon-steel and 79-4 Permalloy rolled to thicknesses down to 0.0008 inches. Even in these thin gages the important magnetic properties of high permeability and low coercive force are restrained.

Cores of this ultra-thin material have also been made by using ceramic spools on which the slit material is wound. The magnetic material and the spool are annealed as a unit at the temperature required to obtain the desired magnetic qualities. Only a few turns of steel are used on each spool, but these are well insulated. Windings are applied by a toroidal winding machine.

There have been some purely commercial developments in the use of these cores, notably for economical purposes. Typical examples include the use of 0.0005 in. cores in the deflection yoke of a commercial television receiver, and the incorporation of these cores into the design of the power transmission for the receiver.

Another interesting application is the use of precision-rolled phosphor bronze in the manufacture of ultra-low-torque potentiometers, which are designed for use as transmitters in indicating or control (servo) circuits.

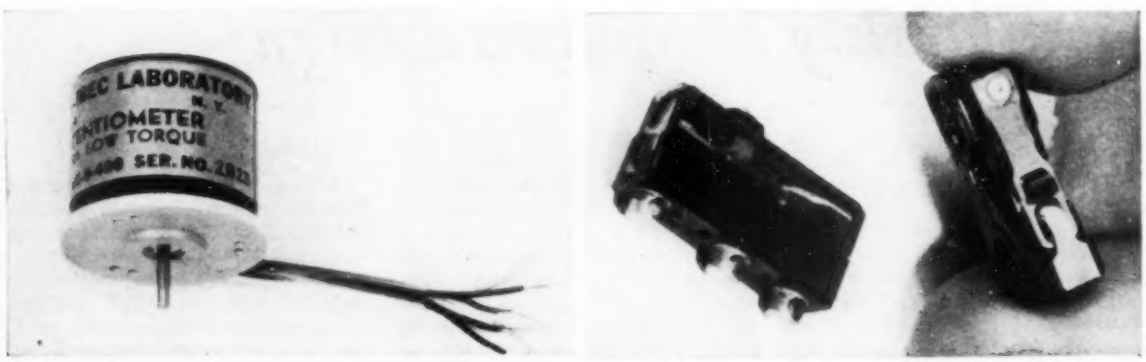


Fig. 3—(Left) This exceptionally low-torque potentiometer for indicating or control circuits uses thin, high-precision phosphor bronze strip. (Right) The micro switch utilizes 0.0005 in. thick beryllium copper strip for its contact springs.

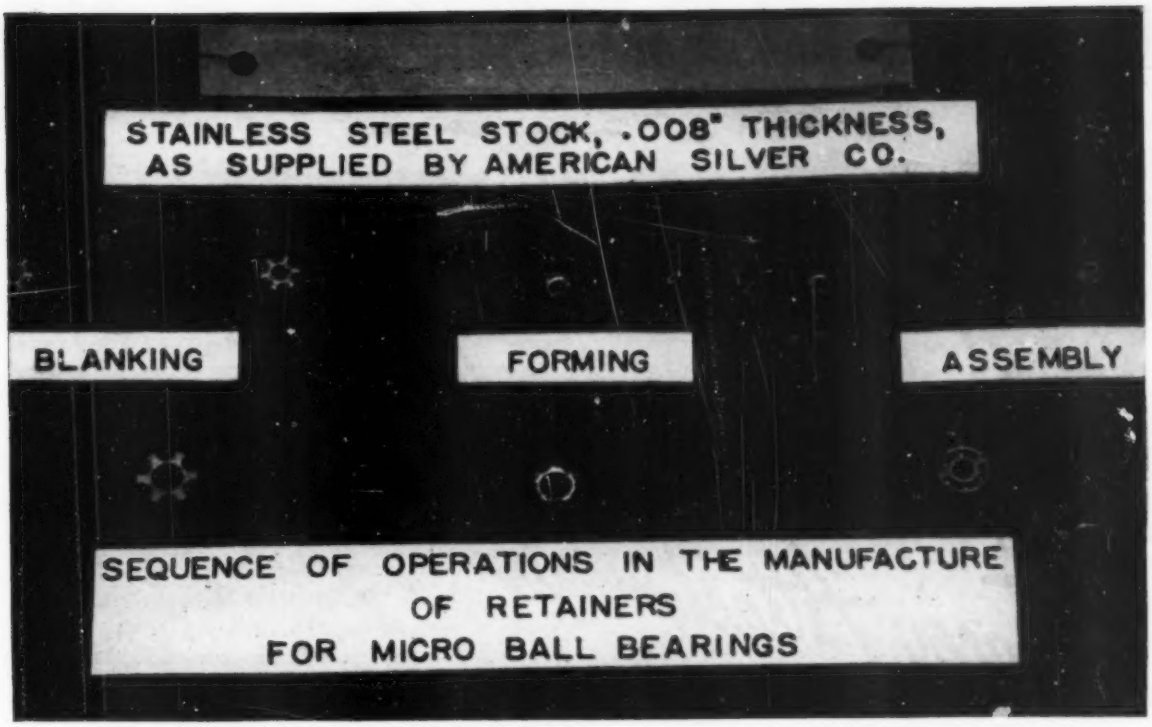


Fig. 4—Shown above is the sequence of operations—blanking, forming and assembly—in the manufacture of retainers for micro ball bearings. Stainless steel strip precision rolled to a thickness of 0.008 inches is used for this part.

The phosphor bronze is rolled down to 0.0016 in. to a tolerance of ±0.0001 in., with a cold reduction of 11 B&S numbers. Ultra-low-torque potentiometers supply torque as low as 0.003 oz.-in., resistance as low as 50 ohms and as high as 125,000 ohms, rotation that is electrically continuous, resolution as high as 1 part in 2,500, output voltage from 0 to 100 percent of input voltage, and linearity as close as 0.5 percent or less.

Instruments of this type are in use in servomechanisms, computers, and telemetering devices of all kinds. Applied to altimeters, gyros, pressure gages, air-speed indicators, accelerometers and compasses, they become electrical transmitting units capable of directly operating remote indicating, recording, or controlling equipment. The small size, weight, and force input have permitted designers to miniaturize assemblies which formerly were too bulky.

Beryllium copper is used in Air Force and Army and Navy type manifold pressure gages—when the metal strip has been rolled to exceptional thinness and tolerances. These gages are designed to indicate the pressure in the intake manifold of an aircraft engine. The precision-rolled beryllium copper functions in the all-important diaphragm assembly.

A prominent instrument manufacturer is using ultra-thin metals in the fulcrum springs on combination furnace controls and snap switches. Thin-rolled monel is used by a wire cloth manufacturer to make the metal clips on the ends of refrigeration dryers. And precision rolled stainless steel strip stock is employed by still another company to make micro ball-bearing retainers. Fig. 4 shows the sequence of forming operations in their manufacture.

There is a growing demand for a steel shim stock rolled to precision thickness tolerances. Some companies have changed their manufacturing methods to take advantage of these new micro-shims. Manufacturers, for example, who once machined parts to within 0.001 in. tolerance by expensive precision grinding, now produce the same parts to commercial tolerances and make up the difference with microshims in increments of 0.0002 in. with a tolerance of ±0.0001 in. High accuracy can be obtained with considerable cost savings.

This micro-shim stock is made from low carbon steel conforming to AISI C 1010 specifications. It is rolled on precision cluster mill equipment to gage tolerances of ±0.0002 in. on thicknesses from 0.010 to 0.006 inches, and ±0.0001 in. on thicknesses below 0.006 inches. The shim stock is furnished with a thin and uniform film of oil in single 6 by 100 in. steel rolls.

In the clad metal field, thin strip promises savings where precious or hard-to-get materials are required. A low cost base metal can be clad with a thin strip of the specific metal required for the surface qualities desired, such as corrosion resistance, electrical properties or thermal conductivity.

Other uses for precision metal strip include decorative trim, instrument paneling, flow regulators, permanent magnet assemblies, variable condensers, locator parts, and telemeter and gyro parts. Thin beryllium copper strip is being used on radar jobs and on sound recording machines; precision rolled nickel alloys are being applied to jet aircraft, heat treating and chemical industries.

Design possibilities exist for these very thin metals wherever a product must be made smaller or lighter, where precious or hard-to-get metals are required, or where special magnetic and electrical qualities are needed. The greater availability of the materials mentioned above should stimulate development and lead to many new applications.

A Look At European Machine Tool Tracer Attachments

In designing tracer attachments for accurate high speed copying of templates, European machine tool builders are using three kinds of mechanisms: hydraulic, electric, and a combination electronic-hydraulic.

Main advantage of hydraulic controls is simplicity. They alter the transverse feed in proportion to the slope of the templet and the components of the system are fairly commonplace: pump, reservoir, pilot valve, power cylinder, piston, and detection unit.

However, hydraulic systems have a tendency to be sluggish. The boundary layer effect reduces the flow of fluid so that actual operation of the tracer unit trails the theoretical. Constriction and contraction phenomena in jets and valves have a similar effect.

Electrical tracer control systems are used where large workpiece dimensions result in low feed rates. With high speed feeds, the time delay caused by switching delays, operating and releasing time of relays, contactors, and electromagnetic clutches, and accelerating time of rotating masses introduces errors that limit the accuracy of tracing.

The electronic-hydraulic system was developed to overcome the sluggishness of a pure hydraulic system and the time delay of a pure electrical system. Electronic valves function practically without inertia, and boundary layer effects are minimized by designing the hydraulic system so that even the smallest displacement of the tracer results in a large and constant operation of the control valve.

In operation, the tracer is connected to an electronic amplifier. Motion of the tracer regulates a small current which is amplified before it passes to the hydraulic control valve. Electromagnets in the hydraulic valve displace the piston valves with rapid movements, thus eliminating intermediate relays and controls.

Here is how seven European machine tool manufacturers transmit tracer action to the cutting tool.

1. Edouard Dubied & Cie. Ltd, Neuchatel, Switzerland, uses a moving hydraulic power cylinder connected to the tool slide to guide the cutting tool. The tracer is connected directly to a pilot valve that moves to supply the fluid to the correct side of the piston which is fixed to the cross slide. The copying slide is inclined at 60 degrees to the centerline of the work to copy turn 90 degree shoulders.

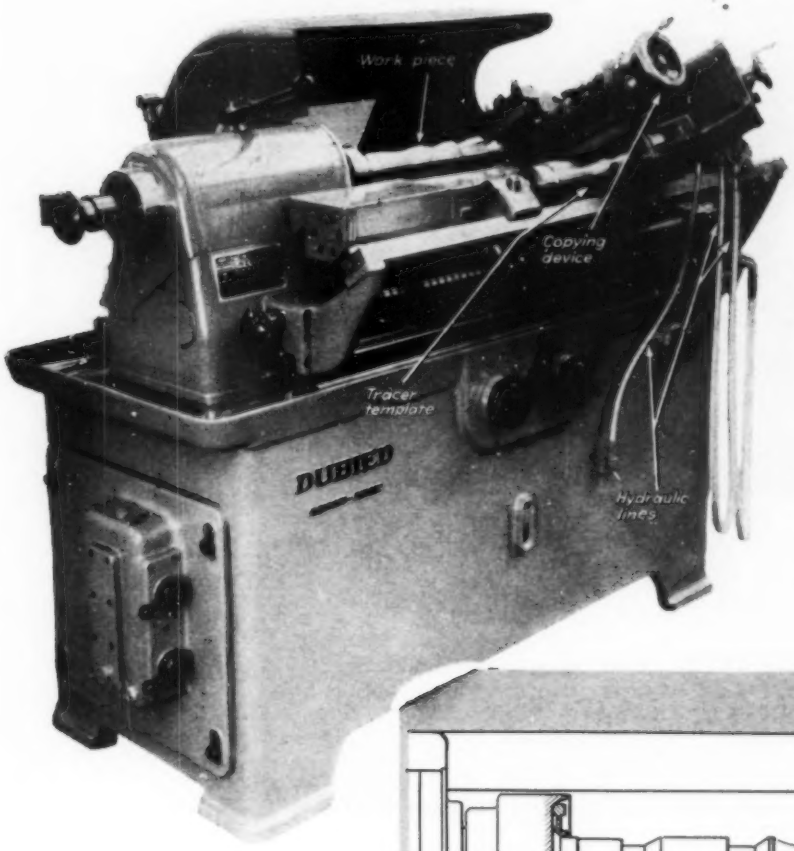
2. George Fisher Limited, Schaffhausen, Switzerland, has placed the copying attachment in a vertical plane with the centerline of the work. Tool motion results from a difference of pressure between a constant pressure chamber and an operation chamber. Movement of the tracer narrows or widens an aperture that increases or decreases the fluid pressure in the operation chamber.

3. Oerlikon Machine Tool Works Buehrle & Co., Zurich, Switzerland uses a moving hydraulic power cylinder. A pilot valve operated by the tracer supplies hydraulic fluid to the proper side of the piston. Main difference between the Oerlikon and the Dubied is in the design of the pilot valve.

4. Heyligenstaedt & Company, Geissen, Germany, makes two types of tracer attachments: A hydraulic and an electric unit. Most interesting feature of the hydraulic tracer is the fact that all parts of the system are contained in the copying slide. There is no external tubing. The electrical control uses a feeder to open and close relays that energize electro-magnetic clutches. Driven by d-c motors, the clutches permit traverse-in, traverse-out, and longitudinal feeds. The feeler is mounted on the tool slide so that it and the tool have the same motion.

5. H. Ernault-Batignolles, Paris, France, depend on a difference of pressure between a constant pressure area and a variable pressure area to get tool movement. Movement of the tracer operates a pilot valve that permits bleeding or building up the pressure in the variable chamber.

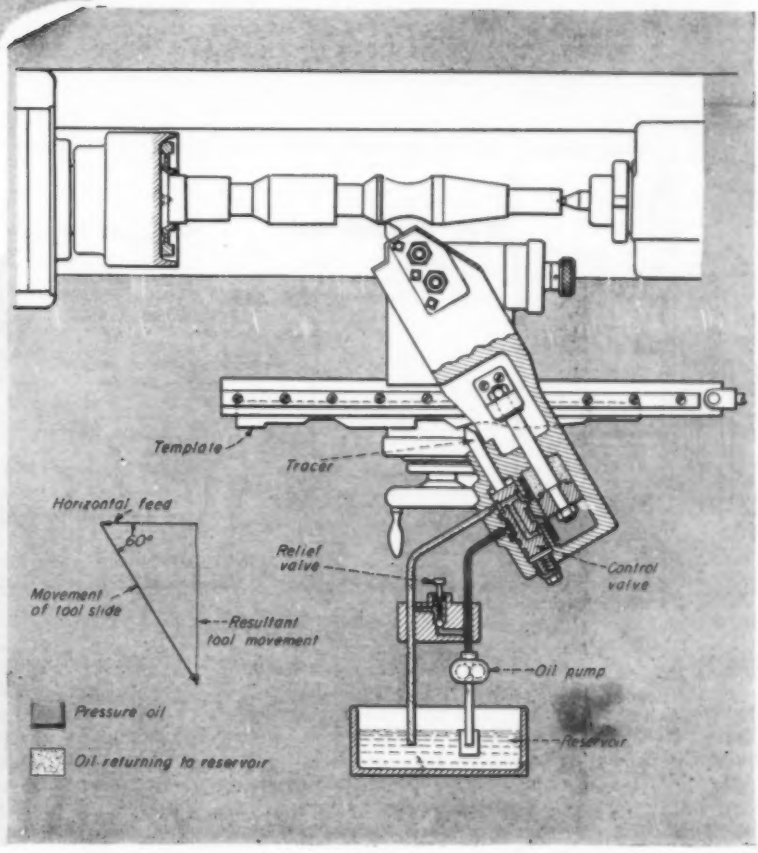
IN NEW PRODUCTS



(LEFT) Dubied 514 high-speed copying lathe uses hydraulic controls and feeds; no electrical or electronic circuits. Copying slide can be inclined at 60 degrees to the work centerline for copy turning 90 deg shoulders.

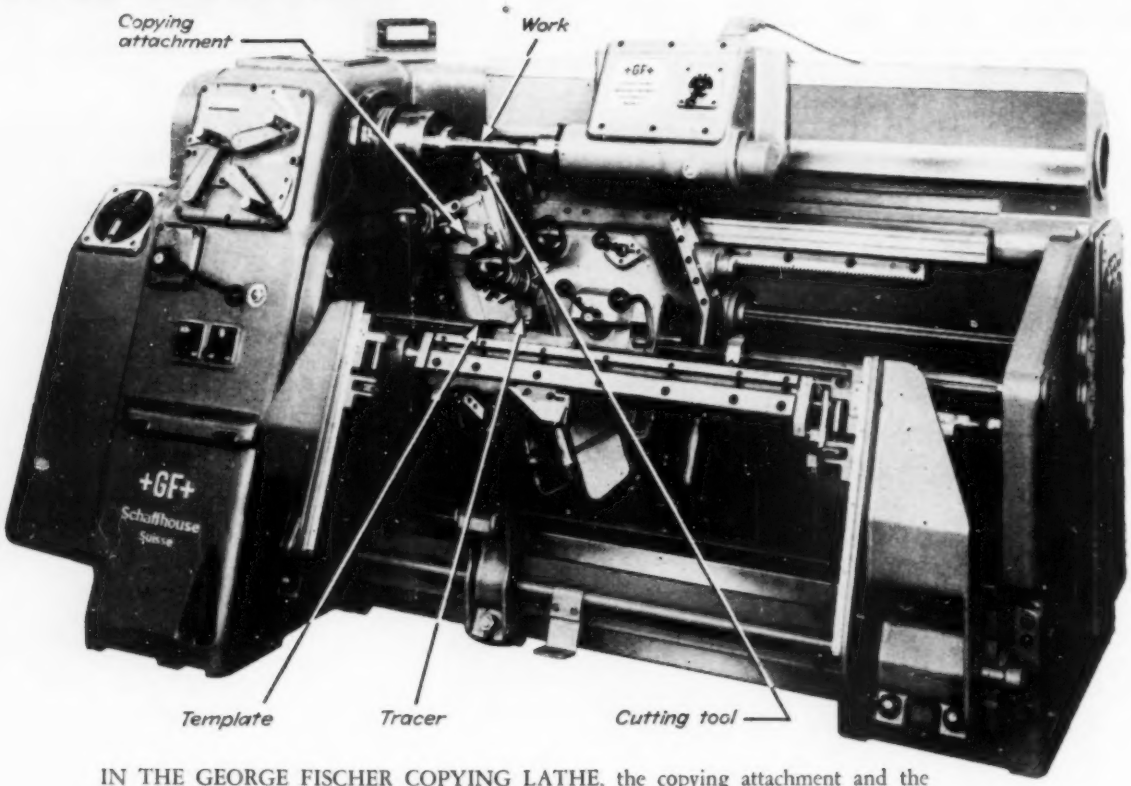
(BELOW) Operation of Dubied copying attachment as tool is withdrawn. Heart of the system is the sliding valve directly coupled to the tracer. Piston is fixed so that movement of the cylinder feeds cutting tool into the work or withdraws it.

(INSERT) Displacement diagram shows how tool can cut 90 deg shoulders. Movement of cutting tool is the resultant action of horizontal feed and 60 degree motion imposed by the movement of power cylinder.

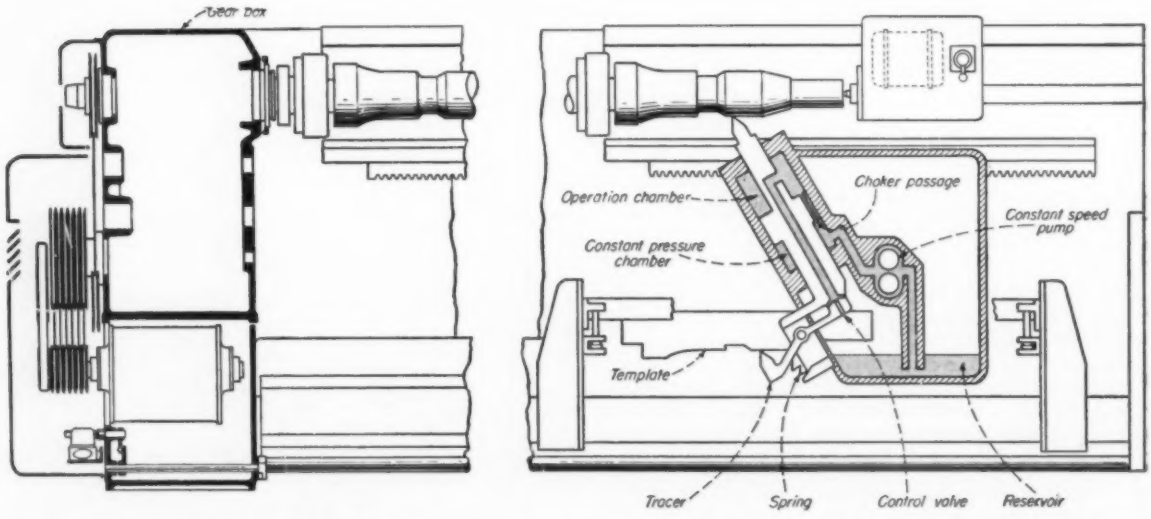


6. Metropolitan Vickers Electrical Co., Ltd. Manchester, England, uses a similar system. Instead of chambers, Metrovick has an ordinary double acting piston. Pressure on one side of the piston is maintained at pump pressure, on the other side pressure is controlled by a pilot valve actuated by the tracer. In this tracer, the pilot valve acts as a hydraulic potentiometer, supplying a variable pressure dependent on the location of the valve.

7. Vereinigte Drehbank Fabriken (VDF) a group of German lathe makers, has developed an electronic hydraulic system that uses electromagnets fed by electronically amplified current to move the hydraulic piston control valves. A power cylinder operates the movement of the tool side.

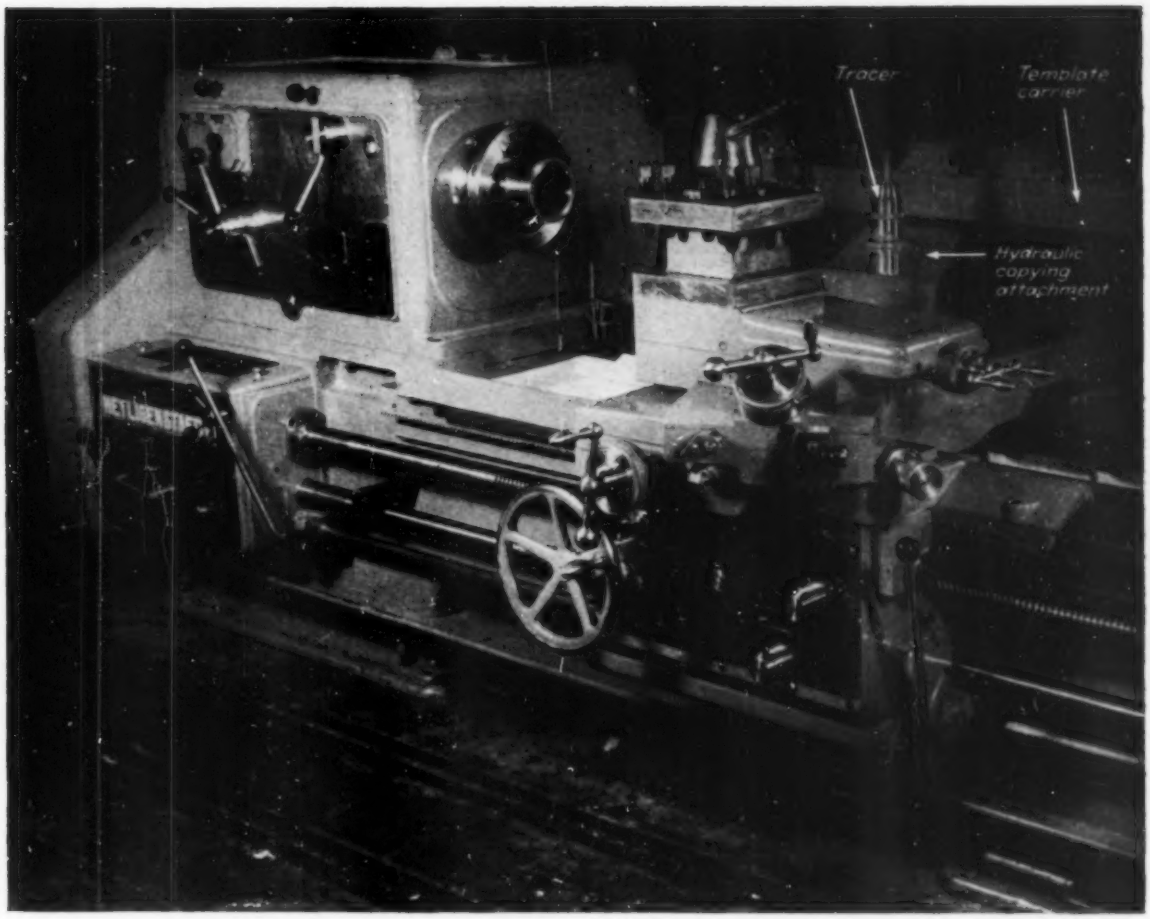


IN THE GEORGE FISCHER COPYING LATHE, the copying attachment and the work lie in vertical plane so that the steady rest does not limit the movement of the carriage. Oil in hydraulic system of copying attachment also lubricates copying slide.

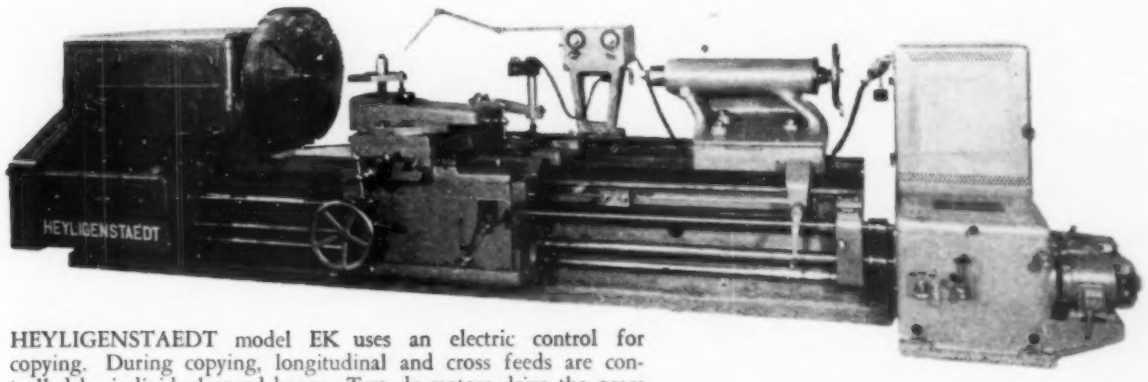


FISCHER COPYING ATTACHMENT. Pump supplies oil to operation chamber through choker passage and constant pressure chamber, and oil returns to reservoir through control valve. When tracer is not in contact with template, spring keeps control valve open and there is no pressure in the operation chamber. When copying slide moves upward until tracer touches template, control aperture is narrowed sufficiently to create a pressure balance between the operation chamber and the constant pressure chamber to stop motion of the copying slide.

When tracer meets a rise in copying template, control aperature is narrowed so pressure in operation chamber increases enough to move slide downward. When tracer meets depression in copying template, control aperature is widened so pressure in operation chamber decreases and pressure in constant pressure chamber moves slide upward.



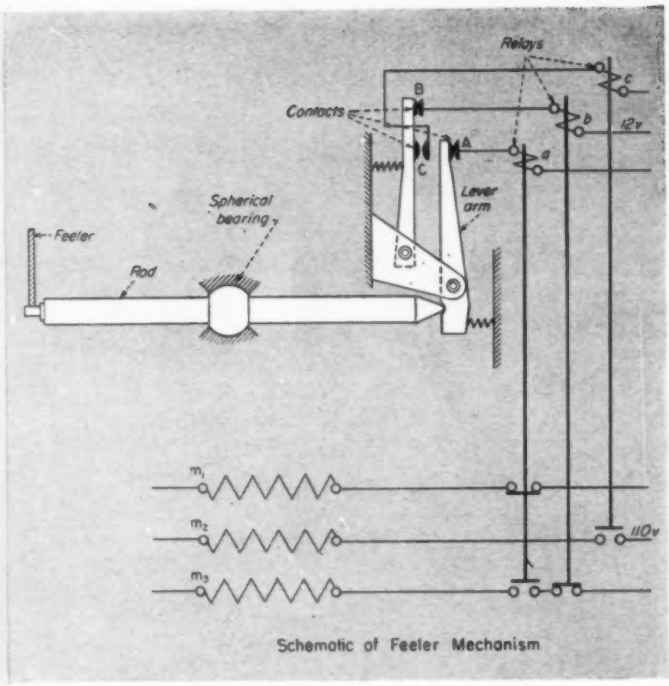
HEYLIGENSTAEDT copying attachment AH-2 is hydraulically controlled but there is no external piping. Parts may be copied from a thin steel template or a master part. To prevent oil leakage, Heyligenstaedt places the control piston inside the rod of the working piston. All the main elements of the attachment, including the feeler mechanism and the templates are located on the rear side of the lathe so as not to interfere with the operator's movements.



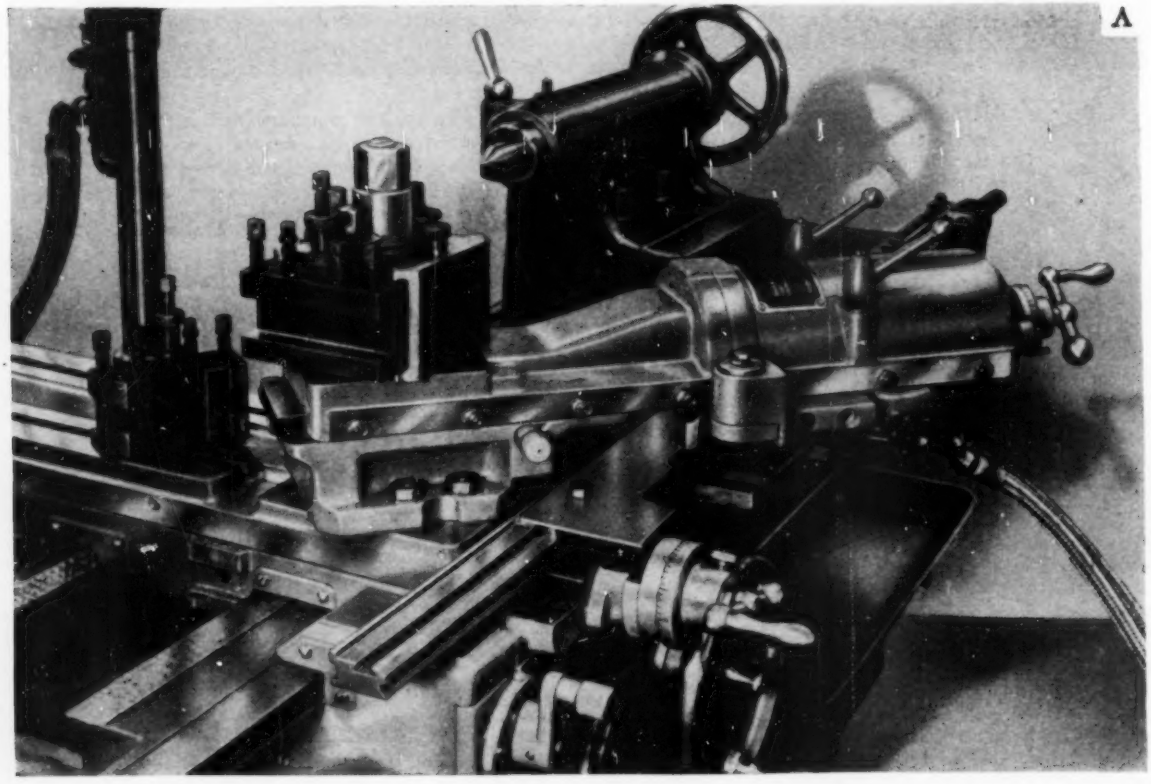
HEYLIGENSTAEDT model EK uses an electric control for copying. During copying, longitudinal and cross feeds are controlled by individual speed boxes. Two dc motors drive the gears of electromagnetic reversing clutches by means of V-belts. Note that electric copying device is used for copying large parts at slow feed.

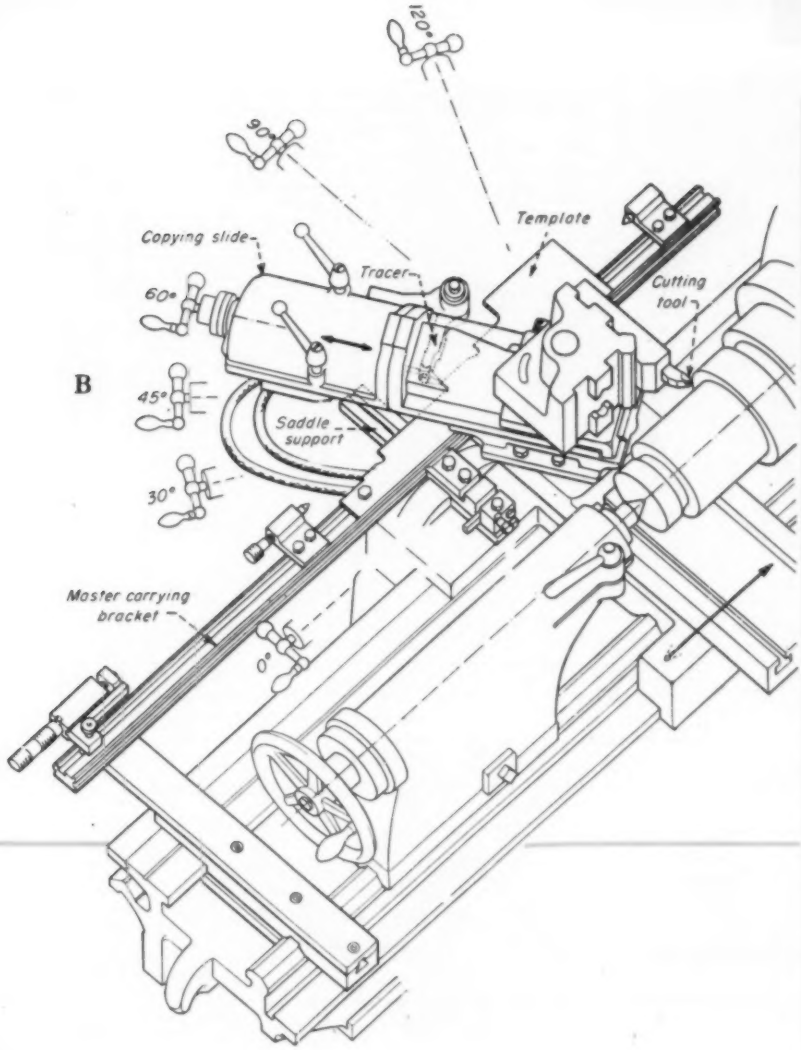
MECHANICAL OPERATION: Movements of the feeler are transmitted by a rod mounted in a spherical bearing to a lever arm that opens and closes contact A, and closes contact C. When mechanism is at rest, contact A and B are held in the closed position by the indicated springs. Since the feeler and the cutting tool are mounted on the same carriage, they carry out the same movements.

Electrical Operation: When feeler is at rest contacts A and B are closed. When working, relay *a* is energized by current passing through contact A thus energizing clutch m_1, which actuates the transverse in-feed. This moves tool carriage toward work and feeler toward template. When feeler contacts template it causes the rod to pivot, opening contact A to stop the cross feed and to energize clutch m_3 which starts longitudinal feed. When feeler strikes a rise on the template it moves the lever arm so that it closes contact C. This energizes relay c; actuates clutch m_2 to furnish outward cross feed.



Schematic of Feeler Mechanism

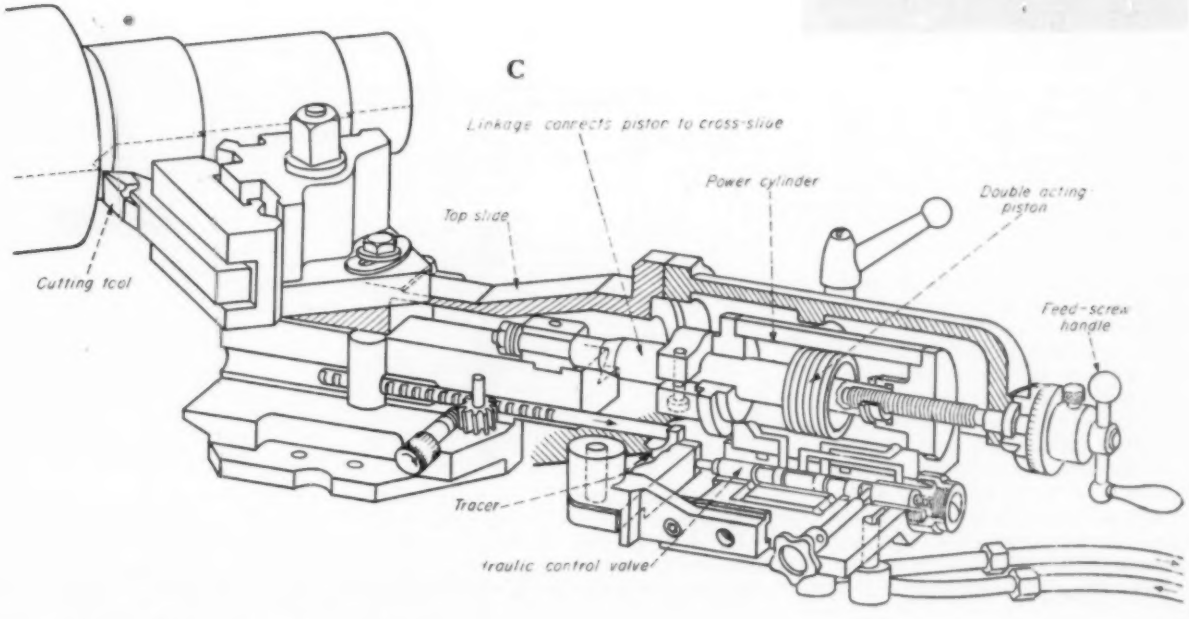


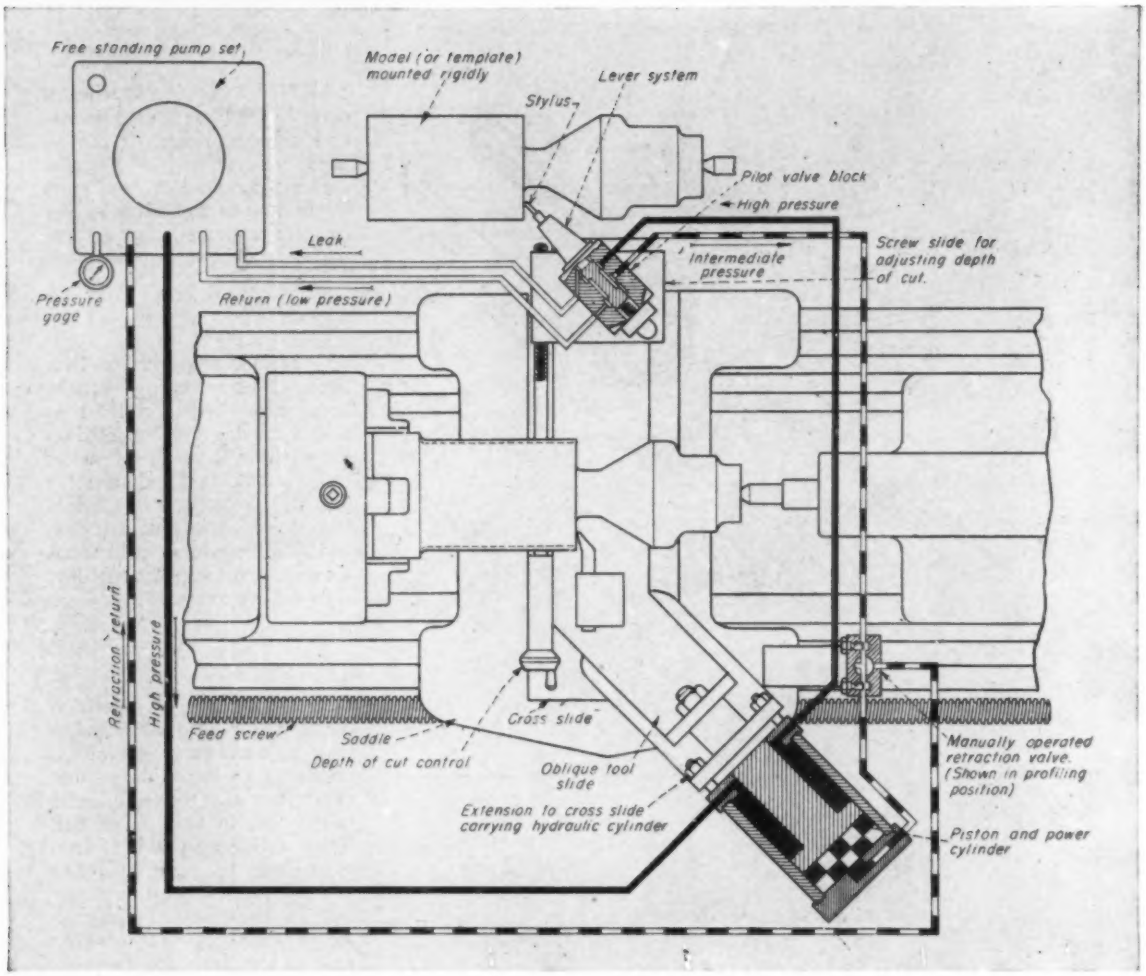


(A) Hydro-Copying attachment made by Oerlikon is used on several different lathes. It can be used for external or internal copying, longitudinal and cross duplicating of increasing or decreasing contours, and reproducing straight 90 deg shoulders.

(B) Main components of Oerlikon Hydro-Copying attachment are: hydraulically controlled copying slide mounted on a cross-slide, longitudinal master carrying bracket, for duplication of a master profile while saddle traverse and cross-slide is at rest, and oil pressure unit (not shown). To increase versatility, slide can be rotated.

(C) During tracing operation double acting piston is locked to cross-slide and power cylinder is connected to top slide so that movement of power cylinder causes tool to feed in or out. Tracer following profile of template moves the control valve to port oil pressure on the proper side of the piston. (Diagram shows operation withdrawing moving tool from work).

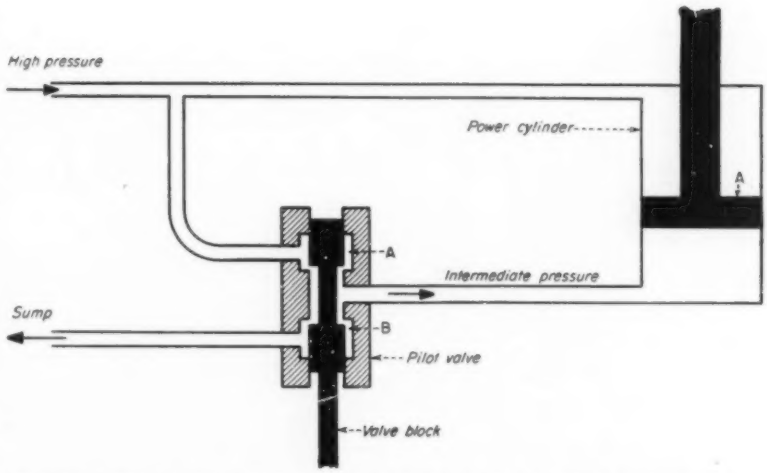




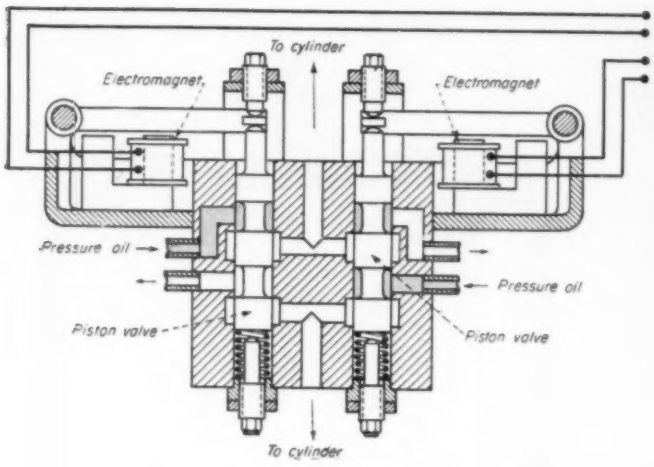
METROPOLITAN Vickers copying attachment operates on a pressure difference. Fluid on topside of piston is always at pump pressure; movement of tracer actuates pilot valve to vary pressure on under-side of piston. To use the attachment, normal tool post is removed and cross slide is fitted with a tool slide that moves obliquely to the bed of the machine.

INTERMEDIATE PRESSURE never reaches the value of pump pressure. Piston is designed so that the intermediate pressure operates on an area twice as large as that on which the constant pump pressure operates. As a result the force provided by the intermediate pressure can override the force provided by the pump pressure to move the cutting tool into the work.

Continuous flow of oil through the pilot valve keeps openings clean and prevents sticking. Oblique tool slide increases range of shapes copied.

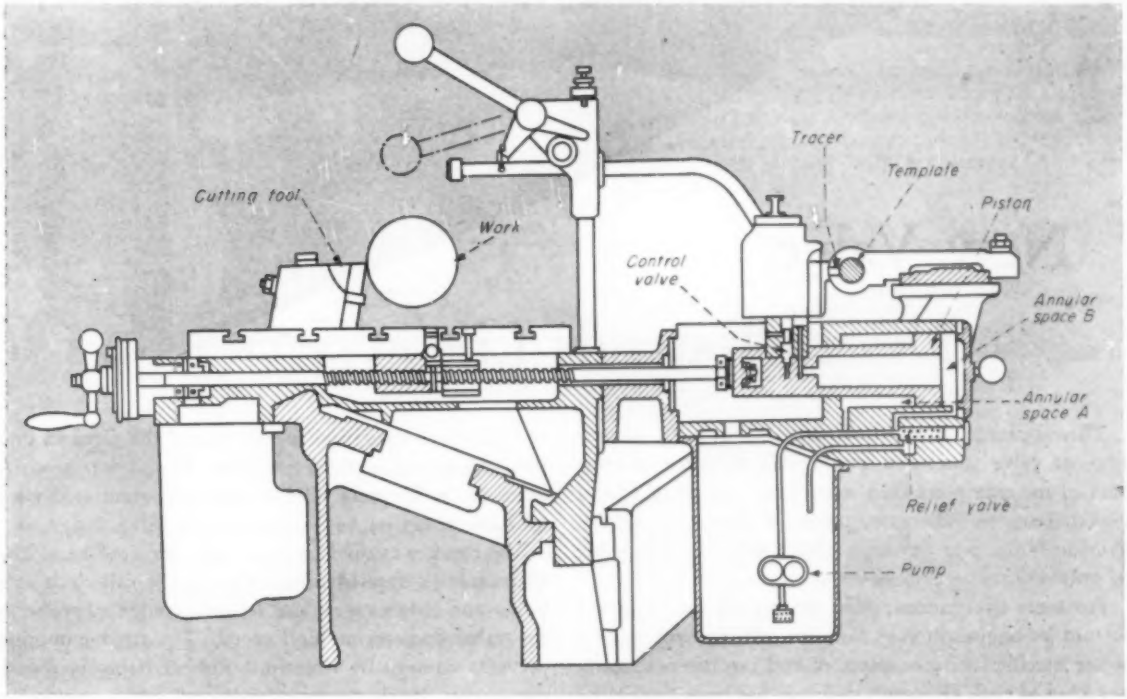


OPERATION of Metrovick pilot valve which acts as a hydraulic potentiometer. If tracer moves valve block up, opening A is increased and opening B is decreased equal amounts so that the intermediate pressure increases and the piston moves upward. If tracer moves the valve block down, the high pressure opening is reduced so that the intermediate pressure falls, piston lowers.



Bauer, Heidenreich & Harbeck

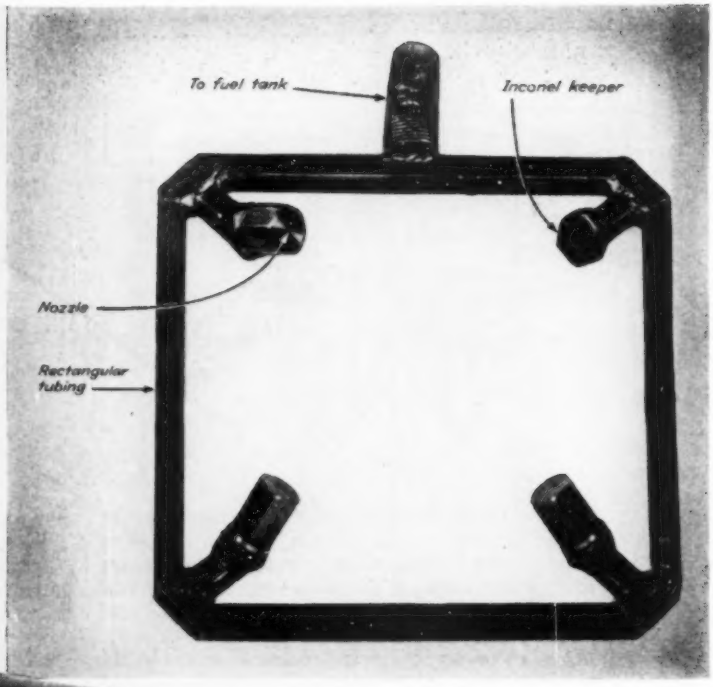
(LEFT) Valve assembly of VDF electronic hydraulic system in zero position. When control voltage to tracer is switched on, magnet system pushes in one of the piston valves, so that oil pressure line is opened and main ram moves the slide with tracer and tool holder in the direction of the template and the work. When stylus tip strikes the template, stylus is displaced to open upper contacts. This deactivates electromagnet so spring-loaded piston valve returns to zero. To withdraw the tool when striking a rise on the template, the stylus moves to close the lower contacts that actuate the other electromagnet and move that piston valve downward. Oil pressure flows so that the ram causes a withdrawal of the tool slide. On reverse slopes, the action is repeated in the other direction. (Right) Close up of VDF attachment on lathe. Control knobs in foreground set steplessly variable longitudinal and transverse feeds.

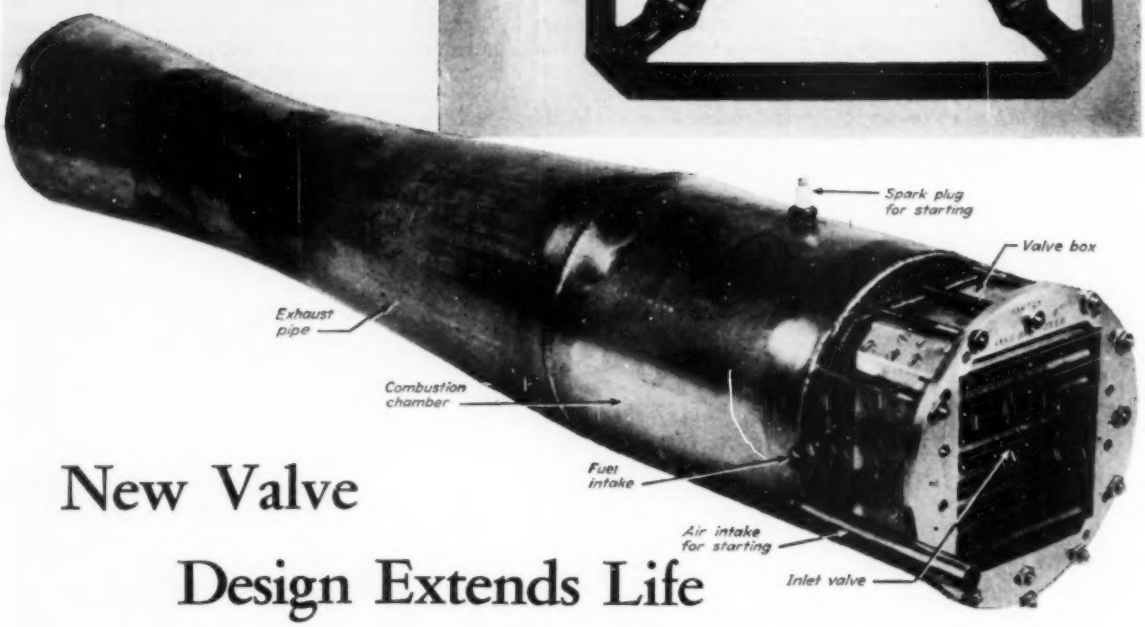


SCHEMATIC of copying attachment made by H. Ernault Batignolles. Device operates on difference of oil pressure between annular space *A* and *B*. Relief valve maintains pressure in area *B*, at a constant 176 psi; the control valve bleeds pressure in Area *A* with movement of tracer. Note that while HEB mounts the tool vertically, the copying feed is horizontal. They claim that this arrangement reduces vibration, increases tool life, and is easier to set up. The copying unit is designed as an integral part of the machine rather than as an attachment for use on other lathes.

FUEL MANIFOLD consists of mild steel rectangular tubing welded together to form rectangular manifold. Nozzles are designed and positioned to cause minimum interference with air flow. Air manifold is similarly made and fits just over fuel manifold.

RESEMBLING a stove pipe, this six in. pulse jet engine, 32¾ in. long develops 40 lb static thrust. Only moving parts are the vanes in the air inlet valve so engine requires no lubrication or cooling.





New Valve Design Extends Life

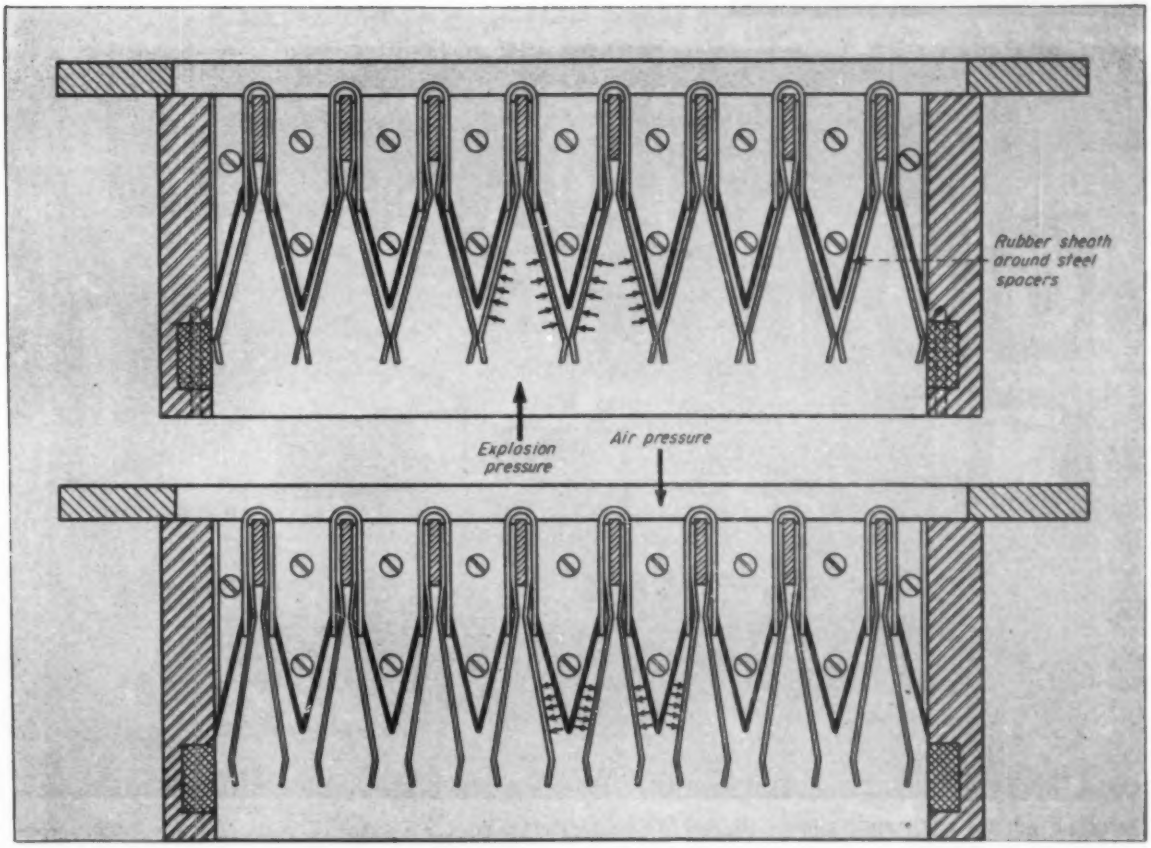
Thermoplastic rubber-like adhesive applied to the edge of valve vanes and the rigid attachment of vane bars in the side plate slots extend the operating life of Naval Research Laboratory pulse jet engines to 200 hr. Previously the best developed NRL pulse jet had a life of only 40 hr.

For some applications, pulse jet engines are preferred to ram jet engines because they are self starting, have a better specific fuel consumption, and can use practically any kind of fuel. However, their use has been limited by their short life.

German Scientists pioneered the development of these engines to power buzz-bombs during World War II. But they never could solve the problem of valve deterioration at high speed operation so that life of the German unit was limited to less than one hour. To develop a power plant for helicopters NRL scientists concentrated on a long-life pulse jet with an improved valve design.

The result was the vane type valve pictured here. The thermoplastic applied to the edge of the valve acts as a buffer and reduces wear and secondary edge vibration as the valve operates at high speed. The rigid mounting prevents damage by vibration. Rubber bumpers absorb the impact shock on vane ends and act as gas seats.

To hold the vanes rigidly in the side slots, each vane bar has a slot 1/16 in. deep by 1/4 in. long that permits locking the valve assembly between the grid side plates. This prevents any shift of the vanes because of centrifu-



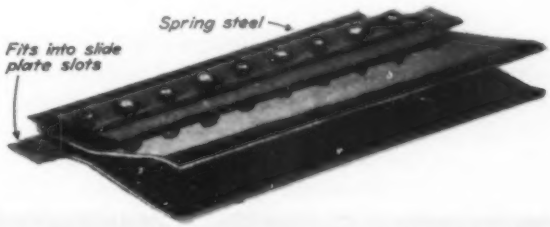
IN STARTING, fuel and compressed air are injected into combustion chamber and spark plug ignites the mixture. During a normal operation, fuel is injected continuously. When fuel explodes, pressure shuts valve forcing gases out exhaust pipe at high speed and developing thrust. As gases exhaust, pressure in combustion chamber drops until outside air opens valve and air enters engine. When air and fuel reach proper proportions, another explosion occurs spontaneously. Frequency of explosions depends on length of exhaust pipe. Unit operates with frequency of 165 cps.

# of Pulse Jet Engine

gal force. The head plate restrains any forward movement of the valve assembly.

There are no critical materials in this pulse jet engine. The body, air inlet and fuel manifolds, as well as the valve box are made of mild steel. The vanes of the valve are ordinary spring steel. The engine is expendable, requires no maintenance, and can be scrapped when its life has expired.

These long life engines have awakened interest in pulse jet engines so that NRL has developed a series of them with combustion chambers ranging from four to eight in. in diameter. One major advantage of these engines is their high output per pound of engine weight.

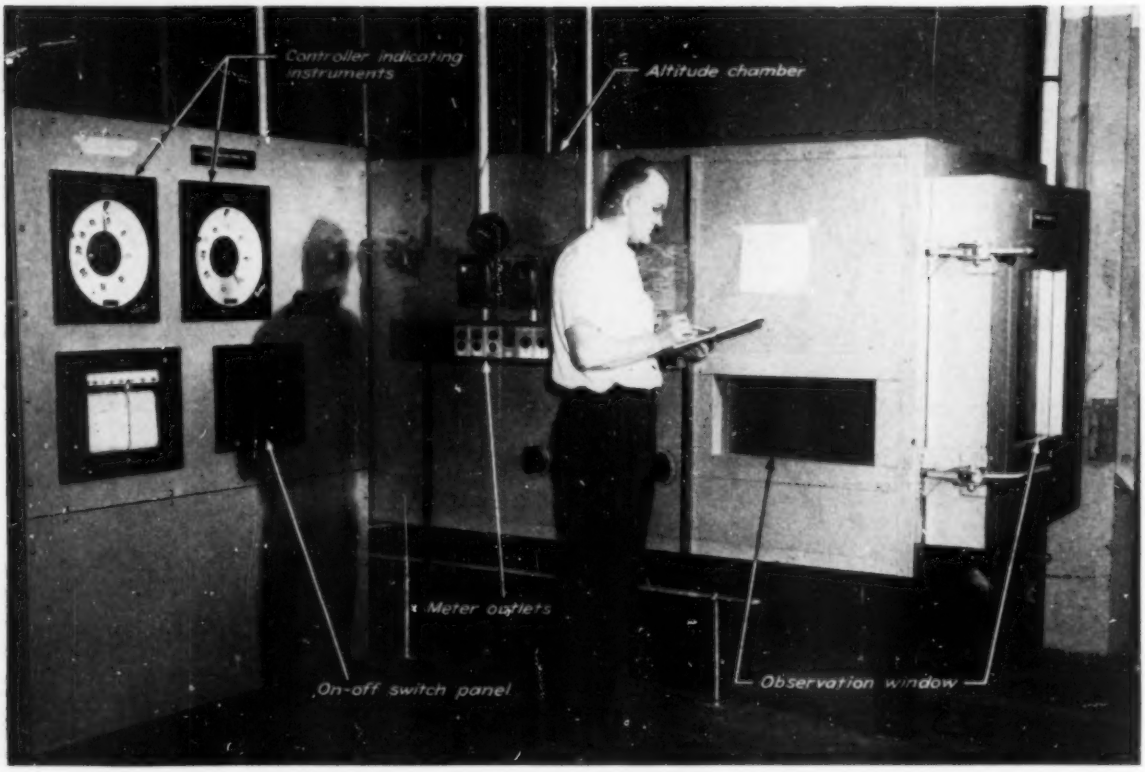


VALVE LEAF consists of two vanes riveted together with an inconel keeper which acts as a leaf spring. Each vane has a piece of silicone Cohrlastic (glass cloth impregnated with silicone rubber) sandwiched between spring steel to act as a buffer against vibration and as a heat insulator.

CHARACTERISTICS OF NRL PULSE JETS

(300 Hr. Operating Life)

Diameter of Combustion Chamber	Length	Weight	Frequency	Thrust
4 in.	29 in.	6½ lb	200 cps	22 lb
6 in.	82¼ in.	11¾ lb	165 cps.	40–42 lb
8 in.	118 in.	27½ lb	120 cps	100–105lb

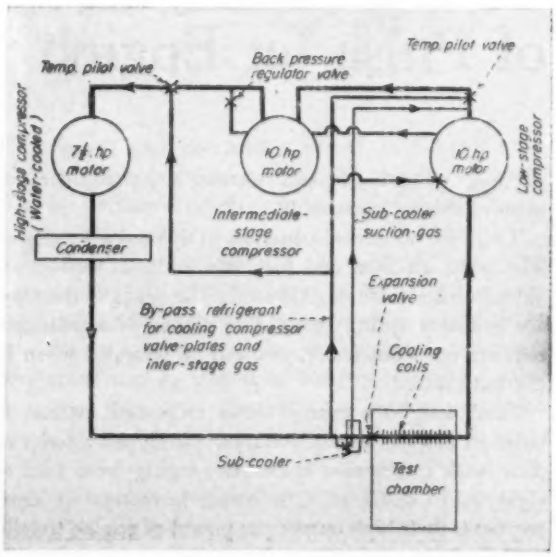


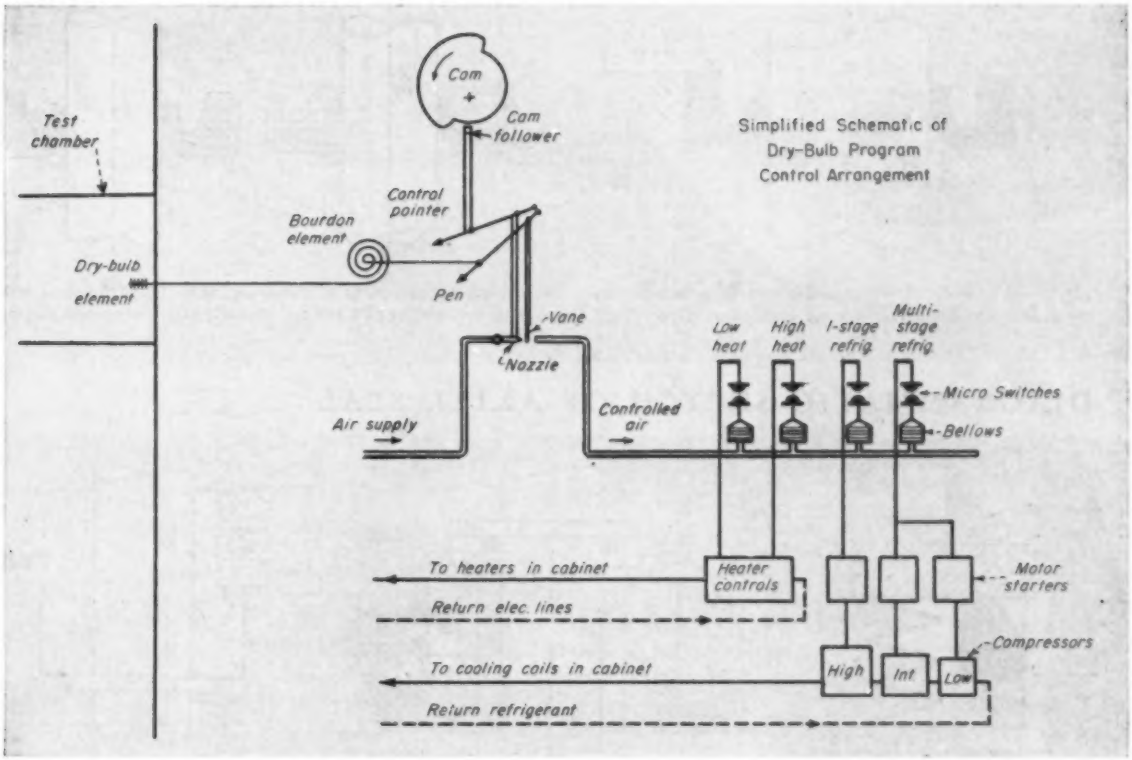
ALTITUDE TEST CHAMBER simulates altitudes to 70,000 ft; temperatures from —100 F to 200 F; and relative humidities from 20 to 95 percent for inspection of aviation components. Control panel contains indicating and recording instruments, and on-off switches. Electrical outlets are for test instruments. Leads to equipment under test enter chamber through special ports. Glass windows permit observation of components during test. Tenney Engineering makes a standard line of these chambers; controls are tailored for a specific job.

Air Jet Operates Environmental

In the altitude test chamber designed by Tenney Engineering, Inc., Newark, N. J., combined action of an air nozzle and a vane varies the pressure of the air in control lines to regulate such properties as simulated altitude, temperature and humidity. Cams position air nozzles in accord with predetermined specifications while measuring instruments in the chamber move the vanes relative to nozzle. This combination varies the pressure in pneumatic lines so that the proper bellows open or close Micro Switches to energize heating coils, refrigeration equipment, vacuum, humidifier, or dehumidifier.

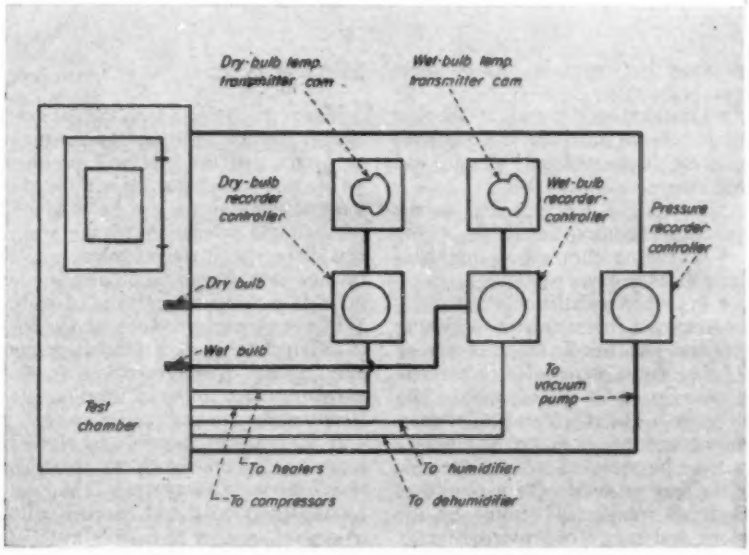
Four air-operated bellows, set to function at different pressure, control temperature: one turns on low heat, one turns on high heat, one energizes the first stage compressor, and the last activates the entire refrigeration system for very low temperature testing. Similar arrangements set up changing conditions of humidity and simulated altitude. The latter being accomplished by pumping air out of the chamber.





TEMPERATURE CONTROL schematic drawing indicates how typical automatic controls work. Cam moves control pointer to specified temperature and at same time positions air nozzle. Dry bulb element measures actual chamber temperature and the result is transmitted to Bourdon element that operates the recording pen and also moves the vane relative to air nozzle. Resulting controlled air pressure acts on a set of bellows which are set to operate at different pressures and which open and close a set of Micro Switches.

Controls in Test Chamber



REFRIGERATOR SYSTEM (far left) uses refrigerant bleeds to improve efficiency. One take-off cools the valve plates of the low and intermediate stage compressors as well as cooling refrigerant gas between compressor stages. A second take-off cools sub cooler which liquifies any refrigerant that may have vaporized when leaving the condensor and cools liquid further.

SCHEMATIC of controls shows that temperature and humidity are automatically program-controlled while vacuum is manually, or single-condition controlled. Instruments are recorder-controller type. Cam, shaped for test cycle, operates elements to produce desired conditions, and recorder charts actual condition throughout test. Cam permits setting up long period environmental test.

DIAGRAMMATIC SKETCH OF RADIAL SEAL

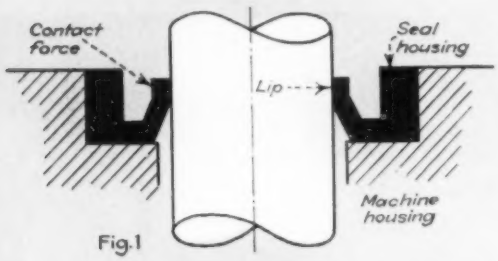


Fig. 1—If capable of withstanding operating conditions, the radial seal often is the most economical type.

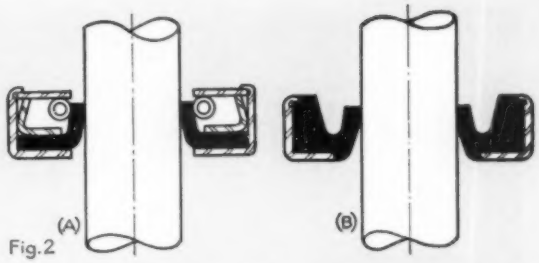


Fig. 2—Some variations of the radial seal: (A) fabricated seal with garter spring; (B) molded in shell; (C) homogeneous seal;

DIAGRAMMATIC SKETCH OF AXIAL SEAL

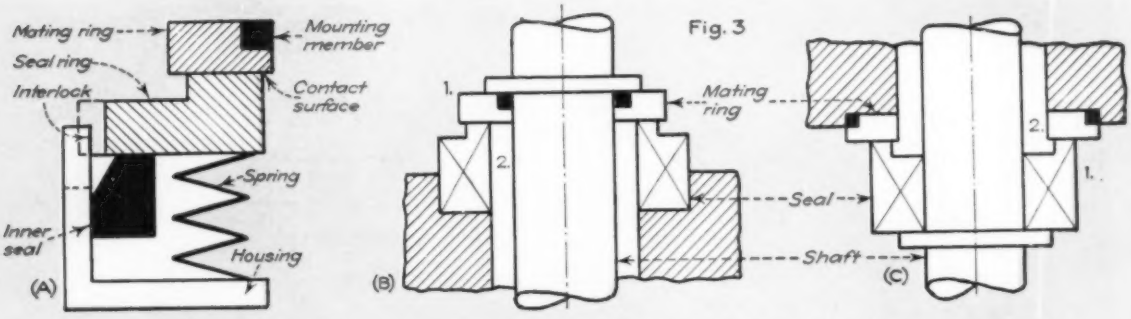


Fig. 3—(A) Essential functional elements; (B) seal that is stationary with shaft; (C) seal that rotates with shaft.

How to Prevent Oil Seal

R. O. ISENBARGER
Chief Engineer,
Chicago Rawhide Manufacturing Co.

OIL SEALS FAIL when they do not perform the functions for which they are required. While this sounds like an obvious statement, their functions are varied and depend upon the particular installation. Generally, the principal function of an oil seal is to prevent the seepage of a medium, liquid or gas, or entry of foreign particles through the space between a moving shaft and a housing—for a specified length of time. The seal may do this, yet fail for other reasons, such as creating too much torque or heat, or grooving the shaft.

The responsibility for failure may often be difficult to determine, but can generally be found in one of these broad categories:

- Considering the seal as the last component in machine design, with resultant haphazard seal design and installation.
- Selecting a seal unsuited to the operating conditions involved.
- Damaging the seal during handling or assembly.
- Improper installation.

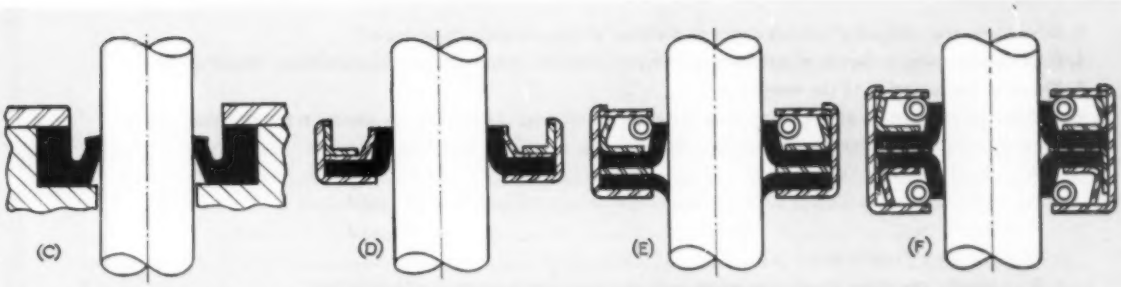
Of utmost importance in obtaining adequate seal life is the necessity of defining the relative value of the seal to other parts in the assembly. The oil seal must be considered a key component and not a necessary nuisance that can be squeezed into an assembly at the last moment. On a pump, as much efficiency may be lost by the wrong seal as by poor rotor design.

SEAL TYPES

When specifying a seal, the designer should consult with the manufacturer to insure that the seal will perform satisfactorily and that it will be the most economical that can be obtained.

A simple tabulation of the many seal designs with respect to use would involve over-generalization and would in itself promote the mis-use of seals. While many variations are merely due to different methods of fabrication not affecting use, minor variations in details may effect ability to function efficiently under specific conditions.

It is, however, possible to classify most seals, with respect to construction, into two general types. The most common, the radial seal, contains a lip or contact member of flexible material



(D) fabricated seal with finger spring; and (E) and (F) two types of double-lip seals. However, the number of constructional modifications and material and dimensional variations of such seals is almost unlimited.

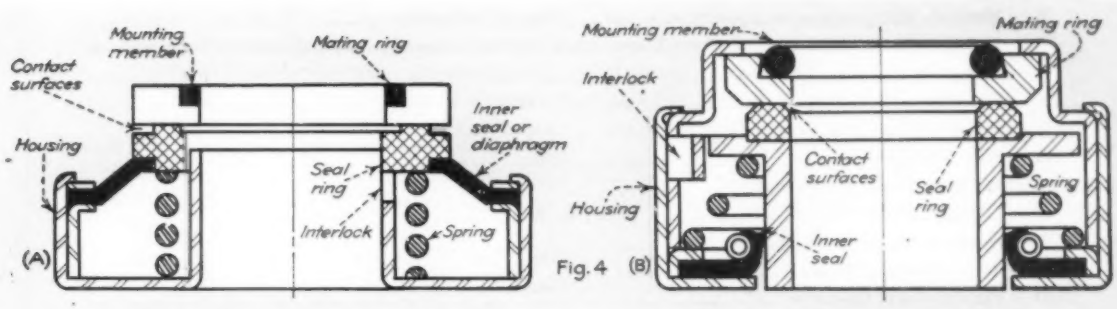


Fig. 4

Fig. 4—Two variations of the axial seal showing functional elements; (A) simple type; (B) complex type.

Failure

Reasons and Remedies for Failure
Check List for Proper Specifications

that forms a sealing contact with the cylindrical surface of the shaft, Fig. 1. The contact force is created by the elasticity of the lip, the pressure of the sealed medium, or a spring of some type. The housing often consists of metal shells that clamp the lip in place, prevents escape of the spring member if one exists, and provides an external surface for press fitting or otherwise securing the seal to the machine housing. As indicated in Fig. 2, great diversification results from various designs and arrangements of the above elements as well as the use of more than one lip member.

The other general type, the axial seal, exerts its sealing contact force parallel to the shaft axis, Fig. 3. Its essential functional elements are shown at (A). The mating ring is usually mounted on the shaft as at (B) or in the housing as at (C).

Two or more of the functional elements may, in a specific seal, be combined in a single member. For example, if sufficient force were exerted by the inner seal or diaphragm, Fig. 4, the spring could be omitted; also if the diaphragm were rigid enough to prevent rotation the interlock could be omitted.

Axial seals may be very simple as shown in Fig. 4 (A), or more complex, Fig. 4 (B), depending upon their use. They will function under more stringent conditions than radial types. Experience has shown, however, that where the conditions are within the range of radial seals, their operation may be more satisfactory than axial types.

STOCK SEALS

Every manufacturer of seals has one or more standard types. Because of existing tooling and quantity production, these seals usually can be produced more economically than specially designed types. A large number of applications fall within the range of these standard seals, and it is advantageous to use them in these cases.

However, there also exist many combinations of conditions for which standard seals are not suitable. In some of these cases, modification of standard designs involving little or no additional tooling may be possible. Also, tooling may exist on types not listed as standard, but which are suitable.

On more difficult installations, it is often necessary to design special seals

CHECK LIST FOR FLUID SEAL SPECIFICATIONS*

1. Give name and address of manufacturer or designer of the assembly to be sealed.
2. Include a drawing or sketch of assembly showing at least the vicinity of the required seal. (See Fig. 6)
3. Describe the operation of the assembly.
4. Include information on any unusual environmental conditions. (Example: Operation in a coal mine.)
5. Give dimensional information and tolerances. (See Fig. 6)
   - A — Shaft Diameter (s)
   - B — Bore Diameter ..... Maximum ..... Desired
   - C — Width (w) ..... Maximum ..... Desired
   - D — Distance From Bearing (a)
   - E — Supply any other dimensions which may be important in particular installation.
6. Give order of assembly of parts by numbers 1, 2, 3, etc., with arrows indicating direction of assembly.

This information will avoid the recommendation of a seal which cannot be assembled. In the event of the use of a radial seal with a lip pointing in the direction of space *B*, it would allow the recommendation of a taper (shown dotted) or the proper assembly tool to avoid damaging the seal when the shaft was inserted. Note also that the drawing tells the seal designer that the bearing will serve as a guide to insure that the shaft will be inserted in the center of the seal to prevent damage.

7. Describe the shaft.
   - A — Material ..... Type
   - B — Hardness R_c ..... Type of Hardening
   - C — Finish ..... Micro-inches RMS as measured by a profilometer or brush analyzer.
   - D — Method of Finishing. Turned
   - E — Ground ..... Polished
   - F — Honed ..... Lapped
   - G — Superfinished ..... Other
8. Outline the Operation of the Assembly.
   - A — Is Operation Continuous? ..... For how long? ..... How long idle?
   - B — Is Operation Intermittent?
   - C — Cycle: Running Time ..... Standing Time
   - D — Peculiarities of Operation
   - E — How much running time is at maximum speed?
   - F — Expected Life Overhaul
9. Discuss Motion of Assembly.
   - A — Does shaft move? ..... Does Housing move? ..... or both
     Describe:
   - B — If motion is rotational, what is speed in rpm? Maximum ..... Normal
   - C — If motion is oscillation, what is speed in oscillations per minute?
     Clockwise Maximum ..... Normal
     Time ..... Dwell Time ..... Counter Clockwise Maximum
     Normal Time ..... Total time for one cycle
   - D — If Motion is Reciprocation? Length of Stroke
     ..... Time for In-stroke
     Dwell Time ..... Time for Out-stroke
     Total time for one cycle ..... Cycles/minute
   - E — Running Eccentricity (e) ..... in in., total indicator reading. See Fig. 7(A).
   - F — Assembled Eccentricity (a) ..... in in., See Fig. 7(B).

This is the amount by which the center of the shaft may vary from the center of the seal assembly due to assembly inaccuracies or tolerances. Due to this eccentricity, the center of the shaft may run at a point not the same as the center of the seal or bore.

to fit the specific conditions involved. Some of these must be considered experimental, and this should be definitely understood between the supplier and user. Seal performance varies even in installations which apparently are very similar. The only way to obtain a dependable determination of seal performance in all but the easiest applications, is to test the seal in the installation for which it is intended.

EFFECT OF OPERATING CONDITIONS ON SPECIFICATION

Most operating conditions are interdependent with four major conditions: shaft speed, temperature, pressure, and materials to be sealed in and out, and these conditions are interdependent among themselves. There is some tendency to consider surface speed or peripheral speed only, since this is the result of both the shaft size and the shaft speed. While peripheral speed is important in determining the frictional temperature build-up and the shaft and seal wear, the ability of a radial seal to operate satisfactorily under eccentricity, wobble and whip, depends upon the ability of the sealing surface to follow this eccentricity, which has a frequency depending upon

G — A wobble is an angular displacement of the shaft axis from its normal position about some center. See Fig. 7(C).

Location of center (c)

Displacement in degrees each side (p) (q)

H — Amount of end play (f)

Some end play is caused in slow movements, due to some such reason as expansion of parts due to temperature rises.

I — Shift (g)

Fig. 7(D) is a variation in a distance between a point on the shaft and a point on the housing, due to assembly tolerances. End play and shift are particularly important in the use of axial seals, since their end movement is limited. Designate points h and k which shift (g) occurs.

J — Describe vibration

This is often difficult to designate quantitively, but is often a reason for seal seepage and sometimes sets up a squeeling noise between the seal and the other machine parts.

10. List Fluid Mediums to be Sealed (See Fig. 6.)

A — Medium at (A) Is this to be sealed from space (B)

B — Medium at (B) Is this to be sealed from space (A)

C — What is level of medium with respect to seal? At A At B

D — Does seal splash or spray, or does it run relatively dry?

Be sure to give exact description of mediums inasmuch as this may be important in determining sealing material which will resist them. If sealing mediums are variable, state range.

E — Give known analine points of the mediums

11. In fractional horsepower units or units using a large number of seals horsepower available for overcoming the frictional resistance of the seals becomes important.

How much horsepower is available for this purpose?

12. Ambient Temperature at Sealing Point (Not Including Heat)

At (A); Max. F; Min. F; Normal F

(B); Max. F; Min. F; Normal F

13. List Pressures. State whether the pressures given are gage or absolute. Absolute pressure designation eliminates negative values used for vacuum gage pressure.

A — (a) Press. Diff. *A* to *B* (When A is Greater) Max. psi; Normal psi

(b) Press. Diff. *B* to *A* (When B is Greater) Max. psi; Normal psi

Either (*a*) or (*b*) may occur or both (*a*) and (*b*) may occur, but at different times.

B — Explain Pressure Cycle

(c) Pressure at *A* max. min. normal

(d) Pressure at *B* max. min. normal

At first thought it may be considered that if (a) and (b) are given, (c) and (d) are not necessary or if (c) and (d) are given (a) and (b) can be derived from them. This is not always true, as the following examples will show. Suppose the differential from A to B is only 25 psi, and this is ordinarily all the seal would have to overcome. The installation, however, is a pump in an oil well where the pressure at A is 2025 psi and at B 2000 psi, the differential of 25 psi being created by the pump itself. Under this pressure, volatile elements in the oil which have never been released are absorbed in the material of the sealing member, so that when the unit is brought up to the surface, the sealing member is distorted and is incapable of sealing. Thus, pressure ranges, as well as pressure differentials, are important.

C — Is pressure pulsating? Describe

* *See text for discussion of above points.*

the revolutions per minute. With an axial seal, the same is true concerning end play. Thus, a 1 in. dia shaft having a speed of 4,000 rpm is a more serious condition than a 4 in. dia shaft having a speed of 1,000 rpm, with the same eccentricity, although the surface speed in both of these two cases is the same.

The amount and type of lubrication reaching the sealing surface is certainly important for its effect upon frictional temperature and wear. Pressure in the medium sealed usually increases the contact or frictional pressure of the seal, increasing the temperature and wear, although some types of axial seals are pressure balanced so that the sealing force is not increased with the increase in the hydraulic pressure. Pulsating pressures are troublesome since they tend to set up vibrations in the sealing surface, interfering with the sealing contact.

Low torque is often a requirement and as such, it may be considered an operating condition. At the same time of course, there must be enough contact pressure to seal.

The amount of heat at the sealing point is determined by seal friction, (which in turn depends upon the materials of the seal shaft, the shaft

speed and the amount and type of lubrication) friction of bearing, friction due to oil agitation, and by dissipation from components such as brakes, clutches and other heat sources. Its amount depends upon these factors as well as the radiating and conducting value of the unit.

The material from which the sealing lip is made must be unaffected by frictional temperature or by the materials being sealed in or out. Deterioration of seal parts may be caused by foreign materials, corrosion and other chemical actions, electrolysis and by impurities in the sealing mediums as well as carbonization of the sealed medium caused by over-heating. Indeed, there exists such a network of dependency that practically every condition is directly or indirectly dependent upon every other condition.

It should be apparent from the above discussion that the submission of pertinent conditions and data along with a sketch of the assembly to the manufacturer will lessen the possibility of failure. A check list for data that should be supplied when specifying a seal is shown in the table. This however, should be supplemented by information on non-coincidence of conditions, and non-operational conditions.

For example, from the information given, it might be assumed that all the worst conditions occur simultaneously, but this may not be so. In a jet engine seal, the highest temperature may not be experienced in flight due to the cooling effect of the air. Instead, after the engine stops, the heat flow through conducting materials may result in higher temperature at the sealing points. Similar conditions of this nature should be reported.

Also, seals are frequently subjected to conditions which are not encountered in operation, but must nevertheless be overcome. Examples are: (1) the baking of a finish on the outside of an assembly that subjects the seals to high temperature; (2) the use of materials for cleaning the assembly that may be injurious to the seal; (3) foreign materials that are encountered in manufacture but not in operation; (4) conditions imposed on the seal during testing which would not be encountered during the actual operation.

A seal that is supplied to withstand arbitrary or artificial conditions within these groupings may not be as good as one designed only to meet service requirements. The same thing may occur if the seal user exaggerates the conditions to be sure the seal will operate satisfactorily over a specified period of time. Example: A seal designed to operate at high pressure necessarily is made heavier and more rigid than one designed to operate at lower pressures. The result is a less flexible unit that will have more of a tendency to "set" away from the shaft. While this tendency may be overcome by a stronger spring, this in turn results in higher shaft friction.

One factor complicating the analysis of operating conditions is that in many cases, these must be determined theoretically. For example, seal performance is often contingent upon shaft material and surface condition, and the type and amount of lubricant present. Ground or lathe turned shafts that have minute flat spots on the cylindrical surface, caused by vibration in the machinery often cause leakage. In specifying surface finish it is not sufficient to merely specify the depth of the microscopic grooves such as is measured by a Profilometer or Brush Analyzer. The character of the surface is also important. Grinding tends to leave sharp, jagged projections, Fig. 5 (A). The seal will usually wear down these peaks, but in doing so, may be seriously damaged. The dotted lines in the figure represent what happens when the surface is polished.

A surface having the same micro

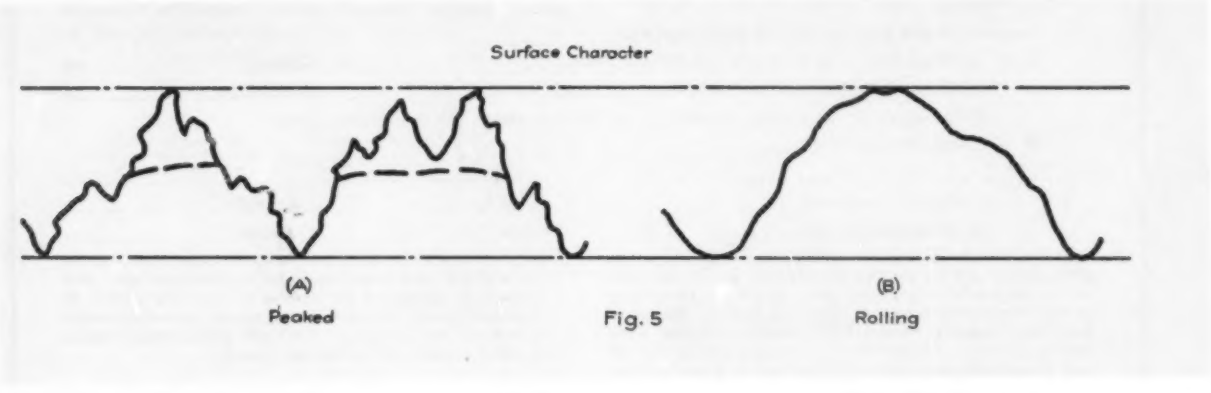


Fig. 5

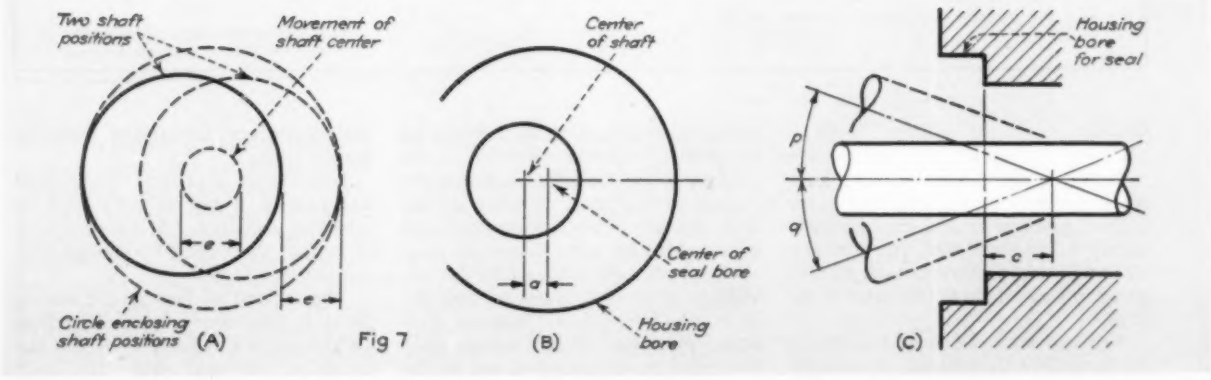


Fig 7

inch reading is shown in Fig. 5 (B). However, it has a rounded or rolling contour which is much easier on seals. A desirable specification for shaft finish upon which a radial seal is to ride would be from ten to fifteen micro inches rms. In addition to this, the surface should be polished with a piece of fine crocus cloth or other polishing medium. While the shaft is rotating rapidly, the crocus cloth should be moved axially until a polish is acquired. As a last operation, the crocus cloth can be held for a few seconds in one spot where the seal is to ride.

Seals not designed for pressure may be subjected to pressure inadvertently by conditions existing within the mechanism. Pressure may be created within the space between a bearing and a seal by a pumping tendency of the bearing. This pressure may be dissipated by drilling a return hole back into the case.

Also, in closed gear cases, pressure may be built up due to heating. This may be relieved by vents so located that they will not be plugged up by dirt or paint. If vents are impractical, high pressures can be avoided by keeping the oil to air ratio space low.

Sometimes the action of gears is such as to throw a stream of oil directly at the lip of the seal, thus raising it from the shaft. This condition is corrected by a slinger or baffle; however, the slinger must be so designed that sufficient oil remains around the seal to prevent lubricant starvation.

Running a seal on a soft shaft or on a shaft made of certain materials may cause the shaft to groove and at the same time decrease seal life. The best material is, of course, steel. Next comes stainless steel. Bronzes, brasses and aluminum may cause difficulty. The surface should be tough, but not brittle, and hardness should range between 45 and 60 Rc. A good grade of chromium plating is often satisfactory.

Finally, miscellaneous causes for failure might be grouped as follows:

1. Paint splashed on the shaft at the sealing lip or on the sealing lip itself at the time the assembly is painted.
2. Excessive bearing wear, causing shaft eccentricity greater than that for which the seal was designed.
3. Chips from machining, worn particles from gears, or dirt left in the housing when the steel is placed on the shaft.
4. Unexpected heat that causes deterioration of the seal directly, or causes carbonization of the oil, which in turn may affect sealing efficiency.
5. Use of lubricants or fluids that were not originally specified and that attack materials in the seal.

Whatever the reason, the cause of failure must be corrected either by redesign or reselection of a seal, or by alteration of the unit. An examination of seals that failed, along with a reevaluation of the conditions that existed at the time of failure, usually points to the reason.

INSTALLATION PRACTICE

Careless or improper installation has ruined as many seals as any other factor. Radial seals, for example, are susceptible to damage in the form of scratches and abrasions on the sealing surface in assembly, over shoulders, splines, keyways and rough surfaces on the shaft. Where it is necessary to assemble over such elements, the seal should be protected by the proper assembly tool. It should be lubricated immediately before installation with a lubricant recommended by the manufacturer. This not only makes assembly easier and minimizes the danger of damage in assembly, but provides initial lubrication for operation of the seal in service.

Radial seals are frequently installed into the housing by press-fitting, the bore being cleanly machined or ground to prevent leakage around the seal. The bore should be held to the tolerance specified by the manufacturer for the seal in question. It is important that the seal be pressed in squarely so that it does not become cocked and, when in place, is square with the shaft. Squareness can be insured by the use of a shoulder against which to press the seal. Press-fitting force should be such that the shell will not be damaged or the interior parts of the seal loosened causing leakage through them.

It is also important to ascertain that the bore into which the seal fits is concentric with the shaft. When a bolted retainer or cap is used, it should be centered by some other means than the bolts alone since the bolt holes allow too much play. It is preferable to pilot the cap in a bore machined at the same time as the bearing bore, or to pilot the cap in the bearing bore.

Axial seals because of their precision parts are particularly susceptible to damage in handling and installation. The flat lapped surfaces of this type of seal are usually packed so that they are together in the running condition, and they should be kept together during handling and installation. Also, axial seals should be carefully handled since even dropping it a short distance can destroy the flatness of the sealing surfaces and cause immediate leakage in service.

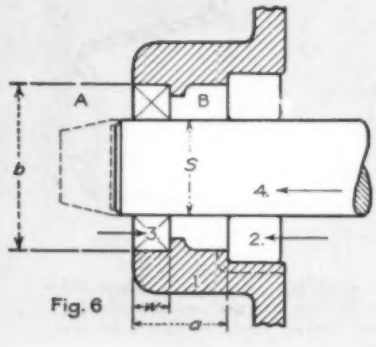


Fig. 6

Fig. 5—Profile sketches of shaft surfaces having the same micro inch reading. The ground surface, (A) has sharp jagged projections that may damage the seal, while the rolled surface, (B) has less effect on performance. Polished (dotted line, sketch (A) is recommended for a ground surface.

Fig. 6—Installation drawing. Arrows and numbers indicate method of assembly. See text for discussion.

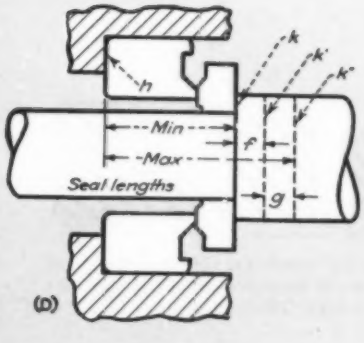


Fig. 7—Shaft conditions affecting seal performance; (A) running eccentricity, *e*, of shaft; (B) assembled eccentricity, *a*; (C) center of wobble or angular displacement, *c*; displacement on each side, *p* and *q*, and end play, *f*; and (D) shift *g* due to assembly tolerances at *h* and *k*. (See table, previous pages).

Tips for Designing Rubber

For economical production, parts should be designed for die cutting in preference to molding wherever possible. When selecting the method of fastening rubber parts to other components, the following factors should be considered: hardness of rubber, operating loads, disassembly requirements,

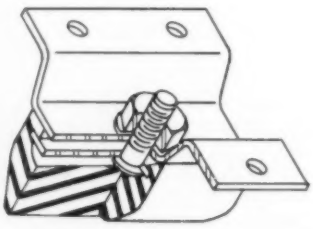


Fig. 1—Holes and slots in molded parts requiring screws or studs are generally preferred to threaded inserts because they eliminate the need for cleaning the rubber from the threads.

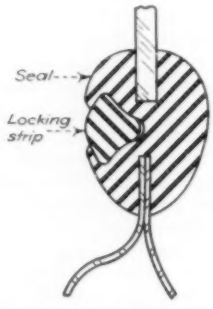


Fig. 2—When it is necessary to seal long peripheries and disassembly may be required, extruded soft rubber seals can be held in place effectively with a locking strip, also made of rubber.

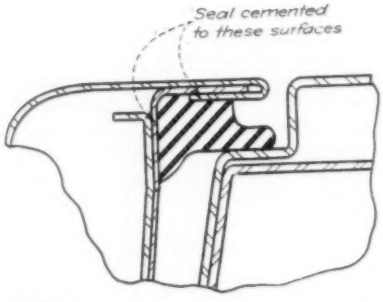


Fig. 3—When the member is subject only to compression loads, soft rubber items can be held to other surfaces with adhesives described in Product Engineering, February 1952.

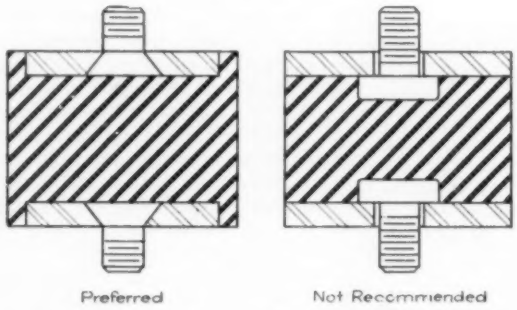


Fig. 6—Uniform sections will reduce adhesion failures where rubber is bonded to inserts and the assembly is subjected to both axial and shear loads. Uniform thicknesses also facilitate molding and eliminate uneven shrinkages.

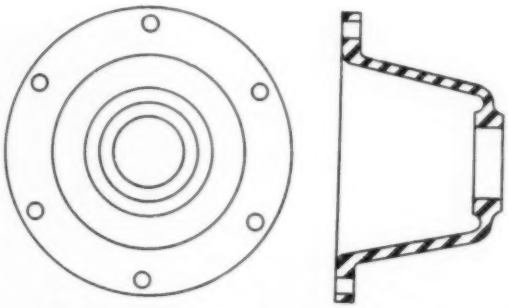


Fig. 7—Space holes in accordance with the hardness and tear resistance of the rubber as well as the rigidity of the metal retainer and applied loads. Molded holes are generally easiest and least expensive to produce.

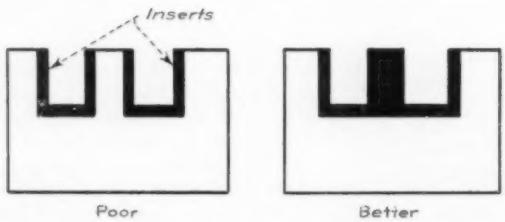


Fig. 11—Small and multiple inserts can increase costs as well as production problems. The single insert shown at the right is preferred to the two smaller inserts at left.

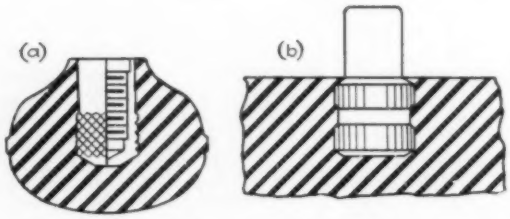


Fig. 12—Coarse diamond knurl (a) is good for most cylindrical inserts. Straight serrations resist twisting but require shoulder (b) to keep from pulling out.

Parts and Assemblies

fabricating equipment availability and production requirements. See page 203, for data on the physical properties of common rubber materials. For additional information on the design and the properties of hard rubber parts see Product Engineering, February 1952, pages 168-172.

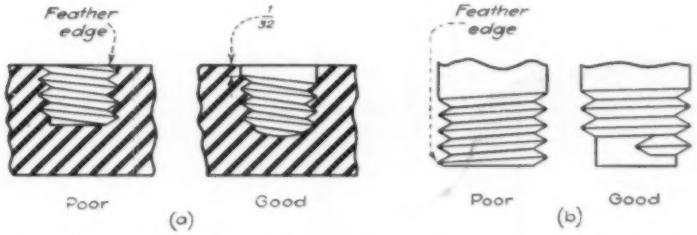


Fig. 4—Molded threads are usually limited to hard rubber items. Unless production requirements are high, they are expensive because of mold costs and the curing time required. On female threads, (a), a recess about 1/32 in. deep extending to the major thread dia will make assembly easier and prevent chipping. Male threads, (b), should start 1/32 in. from the end of the part.

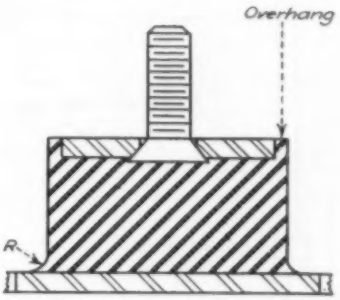


Fig. 5—To reduce adhesion failures in general, all fillet radii should be generous and the rubber should overhang the edges of the inserts whenever possible.

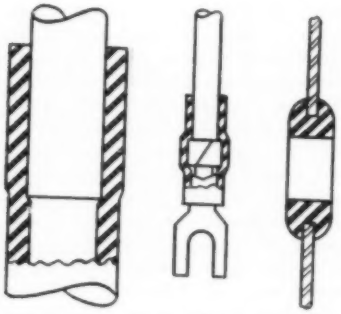


Fig. 8—Select rubbers to take advantage of elasticity to hold parts without fasteners or cement as well as provide leakproof seals in some cases.

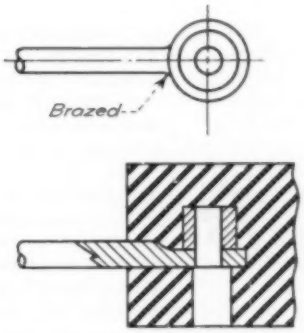


Fig. 9—Projecting ends of inserts should be standard shapes to facilitate pre-positioning in mold. Thin or unsupported inserts may shift in molding.

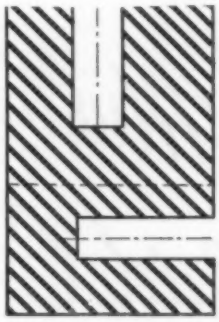


Fig. 10—Avoid holes or slots in two directions to cut production costs. It would be better to make this part in two sections as per the dotted line.

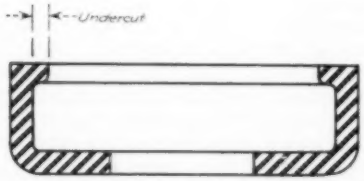


Fig. 13—Avoid undercuts that result in molding difficulties. Size of undercut that will strip easily depends on part size and rubber type.

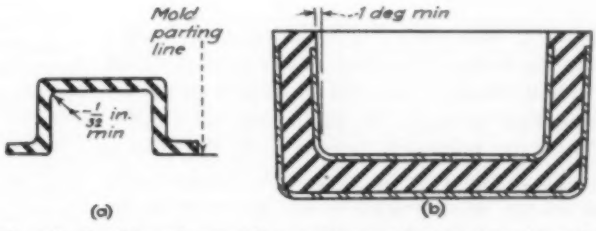
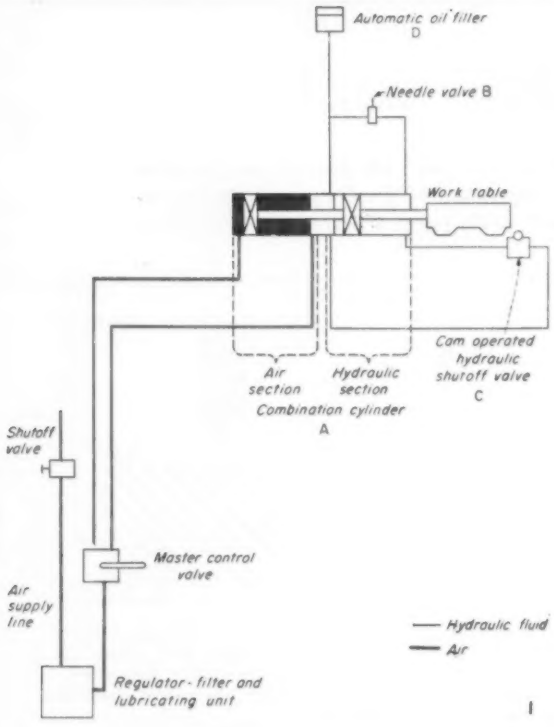
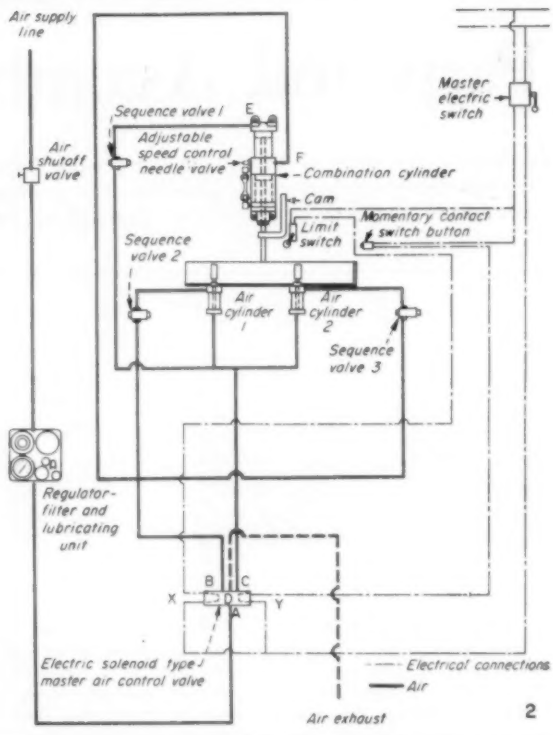


Fig. 14—Consider other molding problems. (a) Use 1/32 min. radius for edges or corners and avoid radii at the parting line. (b) Use draft of 1 degree minimum for surfaces perpendicular to parting line.





Multiple Fluid Circuits

H. L. STEWART
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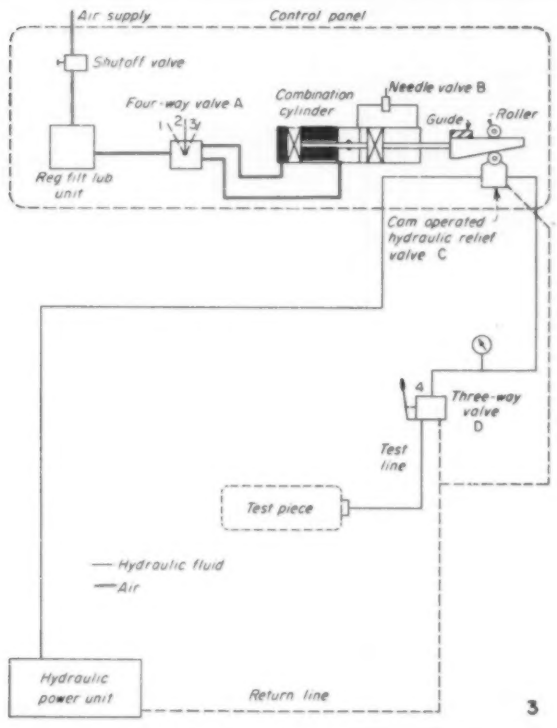
By combining pneumatic and hydraulic circuits in a single system, many fluid power and control problems can be solved which do not lend themselves to the use of a single fluid medium. The rapid response which is characteristic of pneumatic systems, and the smooth action and high power outputs obtainable with hydraulic components can be developed by one system with the proper use of multiple circuits. Where a series of operations must be interlocked to maintain proper sequence, electrically actuated controls can be used. Typical applications of these circuits are shown in the following diagrams.

1. HYDRAULICALLY CONTROLLED FEEDS IN PNEUMATIC POWER CIRCUIT. By using a combination air and hydraulic cylinder with suitable controls, the cylinder in this circuit will produce feeds comparable to those obtained with a complete hydraulic system and speeds comparable to an air system.

The cylinder, *A*, is divided into two sections, a double acting air cylinder and a double acting hydraulic cylinder which have a common piston rod. The hydraulic cylinder is a component in a closed hydraulic circuit which creates no power and only controls the speed of the air cylinder. The speed is regulated by the flow control needle valve, *B*, and by the cam operated valve, *C*. When the operating lever on the cam operated flow control valve is depressed, the valve is shut and the speed of cylinder travel is controlled by the needle valve which can be adjusted for very fine feeds. When the valve *C* is open, the hydraulic fluid flows freely through it from one end of the cylinder to the other, and the work table moves rapidly.

Various combinations of speed and feed can be obtained by changing the shape of the cam. For example, in a tool feed it is usually desirable to bring the tool up to the work rapidly, then feed slowly during the cutting period, and after the cut is completed return rapidly to the starting position. This is accomplished by shaping the cam so that the cam operated valve is shut when slow feed is required. Skip feeds can be obtained in the same manner. The hydraulic piston is designed to give feed control on the outstroke with rapid return, rapid outstroke with feed on instroke, or feed in both directions without the necessity of a cam operated valve. This is satisfactory if a combination of speeds in one direction is not required.

The original cost of this circuit is less than for a complete hydraulic system since it does not require the expensive hydraulic power unit. It is especially adaptable to



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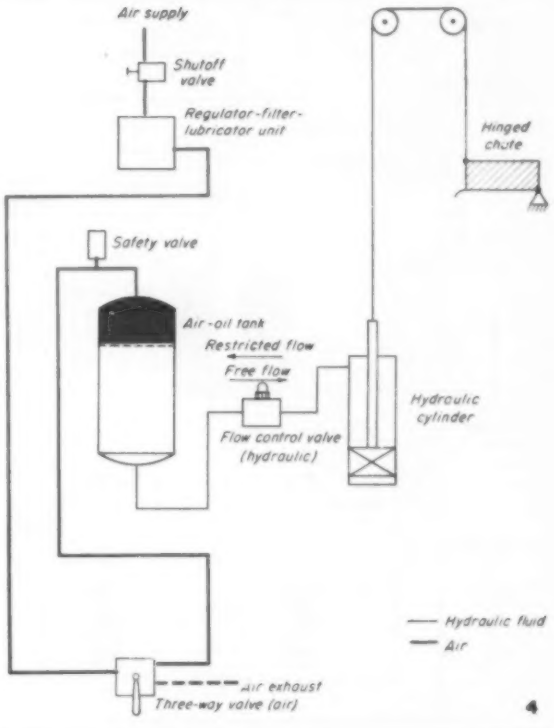

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drilling machines, swagging machines, tool feeds, heat treating equipment and other applications requiring fine feeds but not a great amount of force. The force is limited by the bore of the air cylinder and air line pressure. Other advantages of this circuit are that it can be used in explosive atmospheres and where space is a problem, since as mentioned no electrical power unit is required.

To obtain satisfactory results from a combination cylinder, the closed hydraulic system must be completely full of oil, since air in the hydraulic portion will cause an uneven feed. The automatic oil filler, *D*, keeps the system full and makes-up any leakage that might occur through the rod packing. This unit has a built in check valve to prevent reverse flow of oil.

2. Remote Control of Combination Cylinder. This is a typical machine tool control circuit in which two air cylinders, 1 and 2, clamp the work-piece, while the combination cylinder powers and controls the feed of the tool. A remote control master air valve of the electric solenoid operated type controls cycle operation.

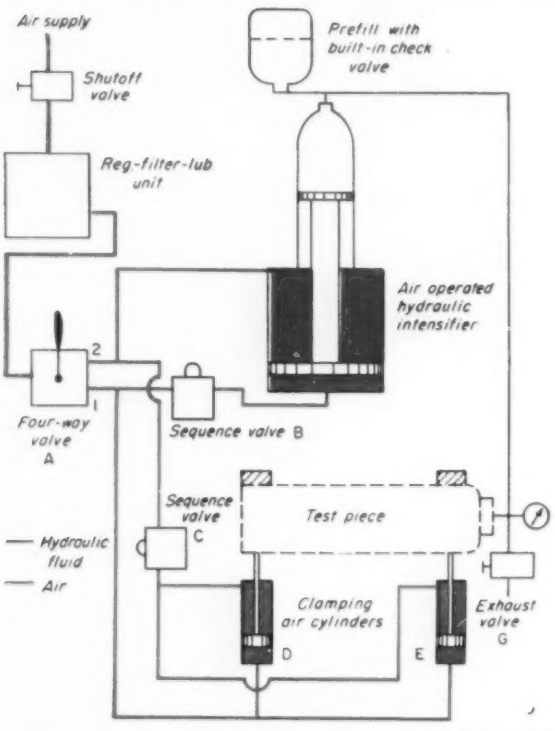
The hydraulic portion of the combination cylinder is again a component in a closed circuit. Its function is to control the feed while the air cylinder supplies the power. When the tool feeds in (downward direction), the flow of oil from one end of the hydraulic cylinder to the other end is restricted by the adjustable speed control needle valve. Thus a slow smooth feed which is characteristic of hydraulically powered devices is obtained. The hydraulic cylinder is designed so that free oil flow takes place on the upward stroke, through a nonreturn valving arrangement, so that a fast return feed is available.

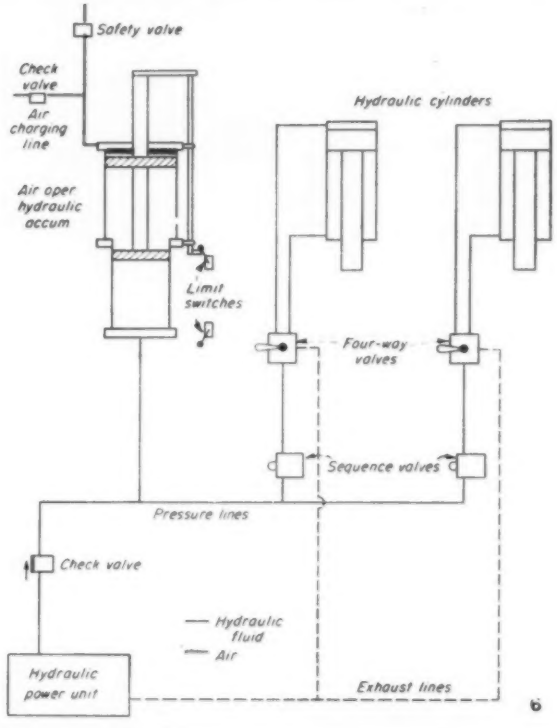
To start the cycle, the momentary contact switch button is pressed, energizing the *Y* solenoid of the master air control valve. Air is directed from valve port *C* to the blind ends of cylinders 1 and 2; clamping the work. When the air cylinders have reached the clamping position, air pressure builds up against sequence valve 1 until its predetermined operating pressure is reached. This valve then opens admitting air to the top of the air portion of the combination cylinder, actuating the cylinder to feed the tool through the work at a controlled rate depending on the setting of the needle valve.

At the end of the feed stroke, the cam attached to the rod of the combination cylinder actuates the limit switch which energizes the *X* solenoid of the master air valve. This valve is not of the spring return type so that only momentary contact of the switch button or limit switch is required. Air is directed to port *F* of the combination cylinder and the tool retracts rapidly, after which air pressure builds up against sequence valves 2 and 3. Valve 3 has a lower operating pressure than valve 2 so that air cylinder 2 releases the workpiece before cylinder 1. This completes the cycle and the machine is ready to handle another workpiece.

3. Multiple Pressures With Combined Fluids. In cases where a range of hydraulic pressures are required, it is sometimes advantageous to regulate the setting of a hydraulic relief valve by means of air operated control devices. This hydrostatic test circuit is an example of this in which an air powered combination air-oil cylinder drives a cam which in turn actuates a variable setting hydraulic relief valve. The low pressure air control circuit and high pressure hydraulic test system are not connected except through the cam operated valve.

At the beginning of the cycle, the cam and rod of the combination cylinder are at the left hand end of the stroke, which corresponds to the low pressure setting of the hydraulic relief valve, and the three-way valve *D* is in the position





which blocks inlet port 4 and opens the test line to the drain. After the test piece is secured, the operating handle of valve *D* is shifted to admit low pressure oil to the test piece for a preliminary check. If there are no obvious faults, the four-way air valve, *A*, is moved to position 3 to admit air to the blind end of the combination cylinder. The piston rod and cam move out at a rate determined by the setting of the needle valve, *B*, which controls the flow of oil from one end of the hydraulic to the other end. As the cam advances, the operating pressure of the hydraulic relief valve, *C*, is gradually increased up to the required maximum. At any point in the stroke the operating handle of the three-position four-way valve, *A*, can be centered (position 2) blocking the ports to the combination cylinder and stopping its travel. This feature is advantageous if several pressure readings are desired from the hydraulic system.

When the hydrostatic test is completed, the handle of valve *A* is shifted to position 1 and the piston of the combination cylinder retracts, releasing the cam roller of valve *C* and decreasing the test pressure to a minimum. Valve *D* is shifted, dumping the oil, and the test piece can be removed.

In the arrangement shown, all the equipment enclosed by the dotted lines is mounted on a control panel.

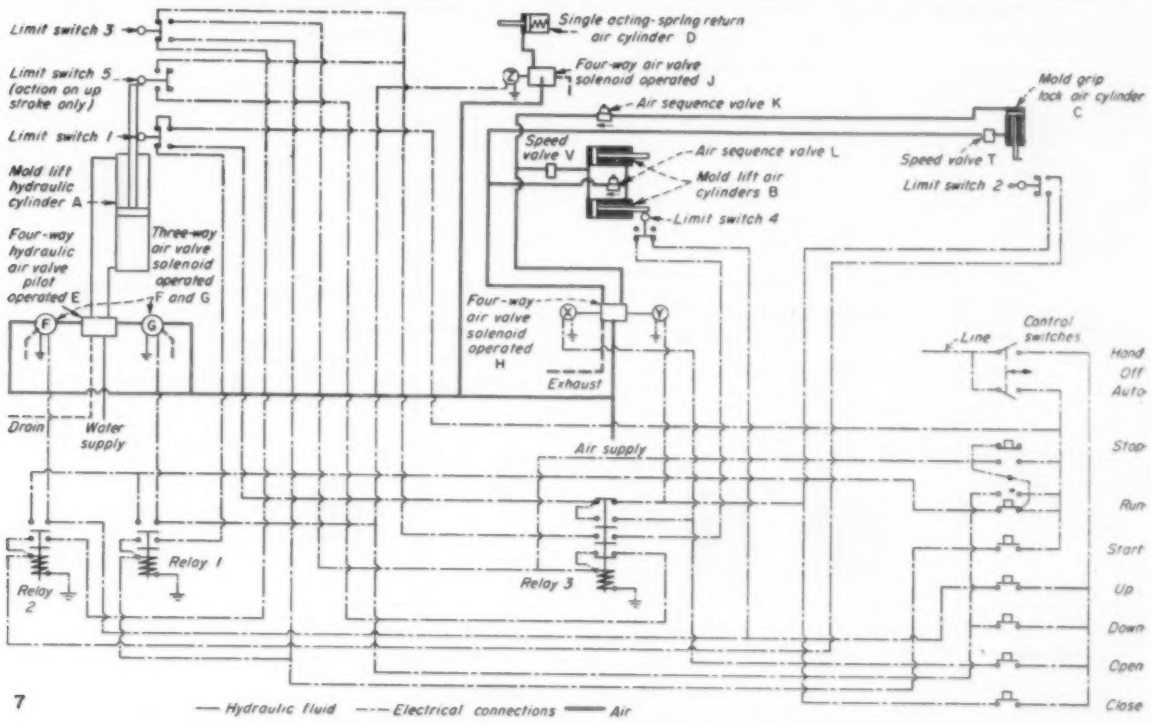
4. PNEUMATIC POWER WITH HYDRAULIC DAMPING. Smooth damping or snubbing action can be obtained without the use of a hydraulic power unit by transmitting power from air to oil in an air-oil tank and restricting the flow of oil with a suitable device. In this circuit, the hinged chute can be rapidly raised to a horizontal position by shifting the three-way air valve, allowing air to flow into the top of the air-oil tank and forcing oil through the hydraulic flow control valve into the rod end of the hydraulic cylinder. This is the free flow direction of the flow control valve.

The chute can be lowered by shifting the handle of the three-way air valve to the exhaust position. This releases the pressure in the air-oil tank and the chute lowers evenly since the oil from the hydraulic cylinder is metered by the flow control valve. The speed at which the chute drops can be regulated by adjusting the restriction in the flow valve. By inserting a hydraulic shutoff valve between the flow control valve and the cylinder, the cylinder can be stopped at any point in its travel. A circuit of this type can be adapted in many ways where heavy objects require smooth handling.

5. INTENSIFIED HYDRAULIC PRESSURES WITH PNEUMATIC POWER. Where high pressure oil or water is required for static purposes, such as hydrostatic tests or press operations, it is often cheaper to use air operated hydraulic intensifiers rather than high pressure hydraulic power equipment, since the latter is expensive and requires high priced accessories.

In this circuit, the test piece is clamped by the air cylinders, *D* and *E*, and then subjected to a high hydraulic pressure developed in the air operated hydraulic intensifier. Intensifiers of this type can be designed to deliver any hydraulic pressure within reasonable limits by varying the ratio of areas of the pneumatic and hydraulic pistons. By using several intensifiers with different area ratios in the same system, a variety of hydraulic pressures can be developed.

To operate this system, the handle of the four-way air valve, *A*, is shifted to deliver air through port 1, to the blind ends of the cylinders *D* and *E*; clamping the test pieces. Then air pressure builds up in the line to the sequence valve, *B*, which opens and admits air to the



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blind end of the air cylinder of the intensifier, *F*. High pressure hydraulic fluid fills the test piece. After the test is completed, valve *A* is shifted to deliver air from port 2 and the intensifier retracts to its starting position. Air line pressure builds up and opens sequence valve *C*, retracting the clamping cylinders *D* and *E*. Valve *G* is then opened to drain the test piece and complete the cycle.

6. Air Operated Hydraulic Accumulator. Since air is a compressible fluid, it can be used in accumulators to store energy or absorb system shocks and pump pulsations in hydraulic systems. In this circuit the differential piston type accumulator is used to maintain system pressure while the power unit is not operating, and to damp line shocks caused by suddenly stopping and starting the flow of oil to the hydraulic cylinders.

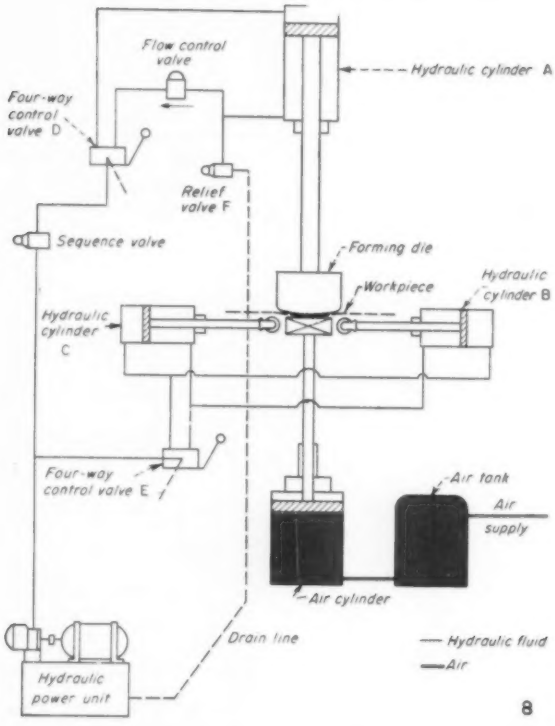
The air cylinder portion of the accumulator is connected to a regulated shop air line through a check valve, so that the air charge is restored to line pressure each time the system is shut down and the accumulator piston goes to the bottom or minimum pressure end of its stroke. This compensates for air leakage. Using this method, limit switches which are actuated by the accumulator piston rod can be used to stop and start the hydraulic power unit and maintain system pressure between a fixed differential. With a fixed reference pressure (regulated shop line), each position of the accumulator piston corresponds to a definite hydraulic pressure, and the minimum to maximum pressure differential can be varied by changing the position of the limit switches. This type accumulator has the disadvantage that the air piston must be large in diameter to meet the pressure requirements of the hydraulic system.

The check valve in the hydraulic supply line prevents the accumulator from discharging back through the pump while the pump is not operating. The sequence valves in the lines to the four-way valves are set so that they will not open below a fixed minimum pressure. This pressure is determined by the function of the hydraulic cylinders, and the force required to perform this function.

7. Pneumatic and Hydraulic System With Electrical Interlocks. In applications where a combination of light and heavy duty operations are required in one system, and where these operations must be interlocked to maintain the proper sequence, a multiple fluid circuit using a hydraulic fluid and air together with electrically actuated interlocks offers a logical solution. The heavy duty operations are hydraulically actuated while the pilot controls and light duty operations are air actuated.

In this mold press circuit, the mold lift cylinder, *A*, (high power requirement) is hydraulically actuated while the lift latch cylinder, *D*, mold lift cylinders, *B*, and mold lift lock cylinder, *C*, (low power requirements) are air actuated. The four-way hydraulic valve, *E*, is air pilot actuated to obtain the high speed of response characteristic of air controlled devices.

At the start of a cycle the components are in the indicated positions. To initiate automatic operation, the selector switch is turned to the *Automatic* position and the *Start* pushbutton pressed. Relay 1 is energized and then held in by limit switch 1, completing the circuit to solenoid *G* of hydraulic valve *E* and to solenoid *Z* of air valve *J*. Hydraulic cylinder *A* moves downward from the half-stroke position, and air cylinder *D* retracts. When cylinder *A* reaches the bottom of its stroke, limit switch 1 is actuated to de-energize relay 1 and completes the circuit to solenoid *Y* of air valve *H* through the *NC* contacts of relay 3. Air flows from the right hand port of valve *H* through speed valve *V* to the blind ends of cylinders *B*, causing them to advance. When cylinders *B* reach the outward end of their strokes,



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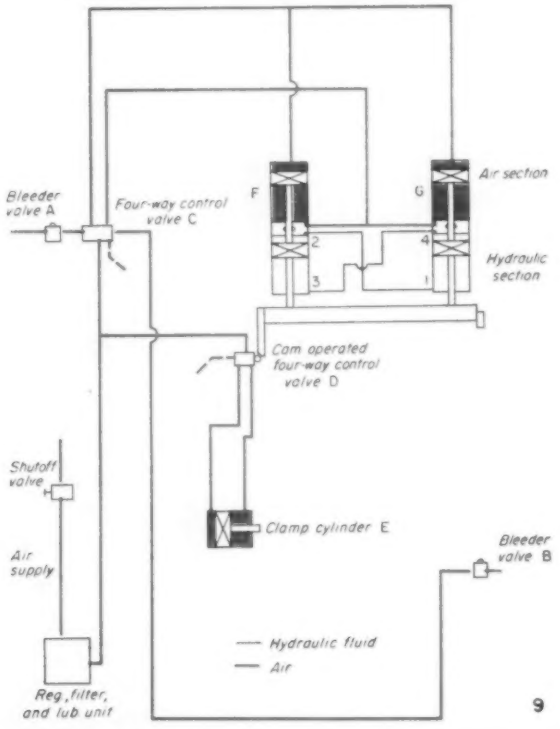

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pressure builds up behind sequence valve *K* which opens causing cylinder *C* to advance. Limit switch 2 is actuated to energize relay 2 through limit switch 1 and the *NC* contacts of relay 3. Relay 2 is then held in by limit switch 3. Relay 2 energizes solenoid *F* of valve *E* and hydraulic cylinder *A* advances to the top of its stroke, actuating limit switch 3 which de-energizes relay 2. Cylinder *D*, which advanced when relay 1 was de-energized, allows the latch to snap into place and all action ceases while the molding operation takes place.

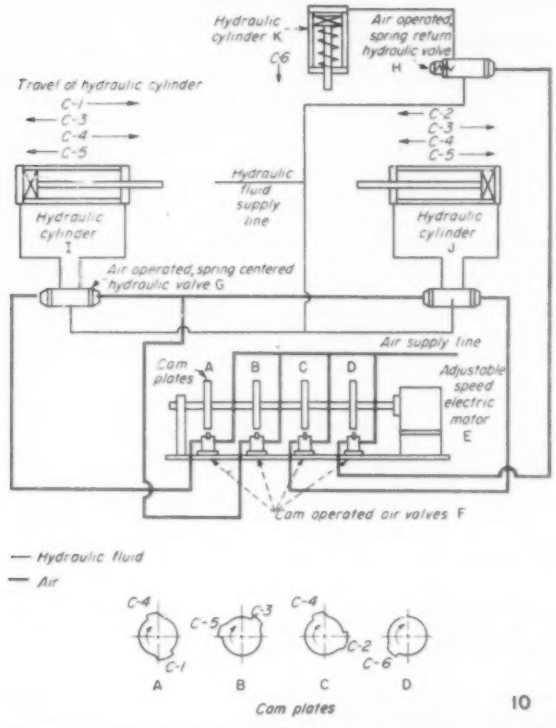
To complete the cycle, the *Start* button is again pressed. Relay 1 is energized and held in by limit switch 1, while relay 3 is energized through limit switch 3. Solenoid *Z* of air valve *J* and solenoid *G* of hydraulic valve *E* are energized and cylinders *D* and *A* retract. Limit switch 1 is actuated to deenergize relay 1 and the circuit to solenoid *X* of valve *H* is completed through *NO* contacts of relay 3. Cylinder *C* retracts after which sequence valve *L* opens allowing cylinders *B* to retract. Limit switch 4 is actuated to energize solenoid *F* of valve *E* through *NO* contacts of relay 3. Cylinder *A* advances to the half-stroke position and actuates limit switch 5 to de-energize relay 3. The cycle is complete with cylinder *A* held by valve *E* which is in its blocked port center position.

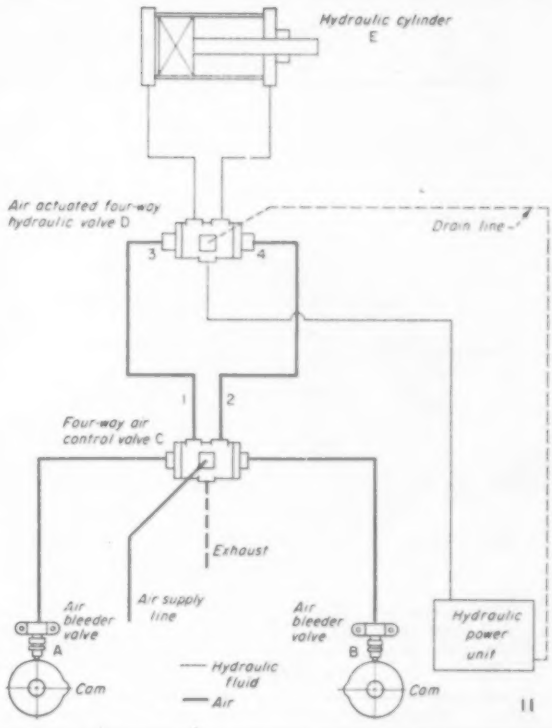
At any time during the cycle, cylinders *A*, *B*, and *C* can be retracted by pressing the *Stop* button. The system can be returned to normal automatic operation by pressing the *Run* button. If hand operation is desired, the selector switch is set at *Hand* and the various components actuated by pressing the proper buttons.

8. Air Cushioning in a Hydraulic System. If a hydraulic fluid is used for cushioning, adjustable bleed devices are necessary to restrict the flow of oil the proper amount. In contrast, since air is compressible, it can be used without accessory devices; the amount of cushioning depending only on the initial pressure in the air cylinder. In this circuit, the air cylinder is used as a cushioner or back-up for the forming die. The air cylinder is single acting and retracts as pressure is exerted on the work piece by the forming die hydraulic cylinder, *A*. The air tank is for storage.

The four-way valve, *E*, is actuated to advance cylinders *B* and *C*. These cylinders maintain tension on the work piece as the forming die descends. Then by shifting four-way valve, *D*, the piston of cylinder *A* advances performing the forming operation. When the work piece is formed, valve *D* is shifted to admit oil to the rod end of cylinder *A*, and the forming die retracts. The flow control valve meters the flow of oil to the rod end of cylinder *A* so that the upward motion of its piston is damped. When the forming die is completely retarded, relief valve *F* relieves the operating pressure during standby periods. Valve *F* is set to relieve at a much lower pressure than the main hydraulic power unit relief valve, since only sufficient hydraulic pressure is required to keep the forming die at the top of its stroke and to retard *B* and *C*, the two tension cylinders.

9. Cylinder Synchronization Using Combination Cylinders. In pneumatic power systems two combination cylinders can be synchronized by cross-connecting the opposite ends of the hydraulic cylinder sections. In this circuit the air sections of the combination cylinders *F* and *G* are used to deliver power, while the hydraulic sections synchronize piston travel. The ports 1, 2, 3 and 4 are connected as shown. Thus, any fluid volume displaced by the lower end of cylinder *F* through port 3 must be absorbed by the upper end of cylinder *G* through port 4. For this method to operate properly the hydraulic system must be kept full of fluid. This can be accomplished by





using an automatic filler. Regulated piston travel can be obtained by adding flow metering valves in the connecting lines.

System operation is initiated by momentarily depressing the lever on bleeder valve *A* which causes valve *C* to shift, admitting air to the blind ends of air cylinders *F* and *G*. These cylinders advance in synchronization, causing the cam to actuate the four-way valve *D*. Cylinder *E* advances, clamping the work. When the lever of bleeder valve *B* is depressed, valve *C* shifts to admit air to the rod end of air cylinders *F* and *G* and they retract. As the cam rides off valve *D*, air flows to the rod end of cylinder *E* and the work is unclamped completing the cycle.

10. HIGH SPEED OF RESPONSE WITH AIR PILOTED HYDRAULIC EQUIPMENT. The use of air piloted hydraulic components combines the best characteristics of both fluid mediums. The high speed of response of the air controls permits cycling of the hydraulic valves with minimum time lag, while the high hydraulic pressure makes available large power outputs with small components.

In this system, the adjustable speed electric motor, *E*, drives the four cams, *A*, *B*, *C*, and *D*, which actuate the cam operated air valves, *F*. The cam lobes are numbered in the order of their operation. Cylinders *I* and *J* advance and retract twice, and cylinder *K* advances and retracts once on one complete revolution of the cam shaft. Cycle time depends on the speed of the motor. This arrangement has the advantage that the sequence of component operation can be changed by merely altering the cam shapes.

11. FAST CYCLING WITH AIR CONTROLS. This is another example of the use of air piloted controls to operate a master hydraulic valve so that high speed hydraulic valve action can be obtained. The rapid expansion of the air shifts the spool of the hydraulic valve without any time lag or hesitation.

In this circuit the rotary cams are mounted on a common motor driven shaft and alternately trip bleeder valves *A* and *B*. The spool of air valve *C* shifts back and forth once each cam shaft revolution, alternately supplying full air line pressure to pilot ports 3 and 4 of hydraulic valve *D*. The spool of valve *D* and piston of cylinder *E* follow the motion of air valve *C*, so that cylinder *E* advances and retards once per cam shaft revolution. The number of times that the piston of cylinder *E* reciprocates in a given time interval depends on the speed of rotation of the rotary cams. By substituting solenoid operated pilot valves for bleeder valves *A* and *B* electric contact control of the master hydraulic valve can be obtained without the use of an expensive high current direct solenoid operated hydraulic valve. If solenoid operated pilots are used, high speed cycling of complicated systems can be easily controlled from a drum type multiple electrical contactor.

In addition to the higher speed of response which can be obtained with air pilot controlled hydraulic valves, they also permit the use of open centered hydraulic valves without any restriction in the hydraulic pressure line. An open centered hydraulic valve returns the fluid directly to the tank when the spool is centered. Thus the hydraulic power unit delivers fluid at a low pressure which is only sufficient to overcome line friction, except when the valve is actuated. When the valve spool is shifted, the return port is blocked, and fluid pressure builds up to the relief valve setting. If the hydraulic valve is hydraulic pilot actuated a restriction must be placed in the pressure line since some pressure is always required for pilot operation. The hydraulic power unit is never completely unloaded and its power consumption is higher. With air pilots, hydraulic pressure is only required during operating portions of the cycle.

Table I—Principal Induction Generator Errors

Type of Error	Components of Errors		Sources of Error Voltage	External Conditions Affecting Errors
Residual voltage at zero speed	Fundamental frequency voltage independent of rotor position	In-phase*	Unsymmetrical magnetic circuit. Nonuniformity of magnetic material. Irregular machining of air gap surfaces.	Primary voltage, temperature, strained housing caused by careless installation.
		Quadrature**		
	Fundamental frequency voltage varying with rotor position	In-phase*	Nonuniformity of drag-cup caused by nonhomogeneity of material and irregular machining.	Relatively independent of external conditions.
		Quadrature**		
	Harmonic frequency		Excessive flux density causing saturation. Nonuniform permeability of magnetic material due to mechanical strain and directional properties.	Primary voltage, frequency.
Nonlinearity	In-phase voltage*		Leakage reactance and resistance of primary winding causing reduction in primary flux with increasing speed. Rotor leakage also causes nonlinearity, but effect is negligible in drag-cup.	Relatively independent of external conditions.
	Quadrature voltage**			
Voltage gradient and phase angle errors at low speeds	Gradient		Inaccurate standardization of phase angle and gradient by manufacturer. Deviation from conditions under which standardization was performed.	Temperature, primary voltage, frequency.
	Phase angle			

* In-phase error voltage is fundamental frequency error in time phase with the rotational voltage at low speed.
** Quadrature error voltage is fundamental frequency error voltage in time quadrature with the rotational voltage at low speeds.
H—Closely held tolerances, small errors. L—Large errors, loose tolerances.

Performance Characteristics Induction Generator

Operating principle, types of errors preventing ideal performance and how to correct for them, application suggestions, and sample performance calculations for units under service conditions.

ALTHOUGH the induction generator tachometer is widely used in alternating current control circuits and analogue computers, many of its features and limitations are obscure to the system designer. The application of high quality, standardized induction tachometers to systems in which load, temperature, frequency, and other variables are close to standard does not present a difficult problem. However, if a tachometer operates under nonstandard conditions, or if less expensive nonstandardized units are used, compensation or standardizing networks must be added to obtain satisfactory performance. To design these networks, consideration must be given to the errors and peculiarities of the device in relation to the application.

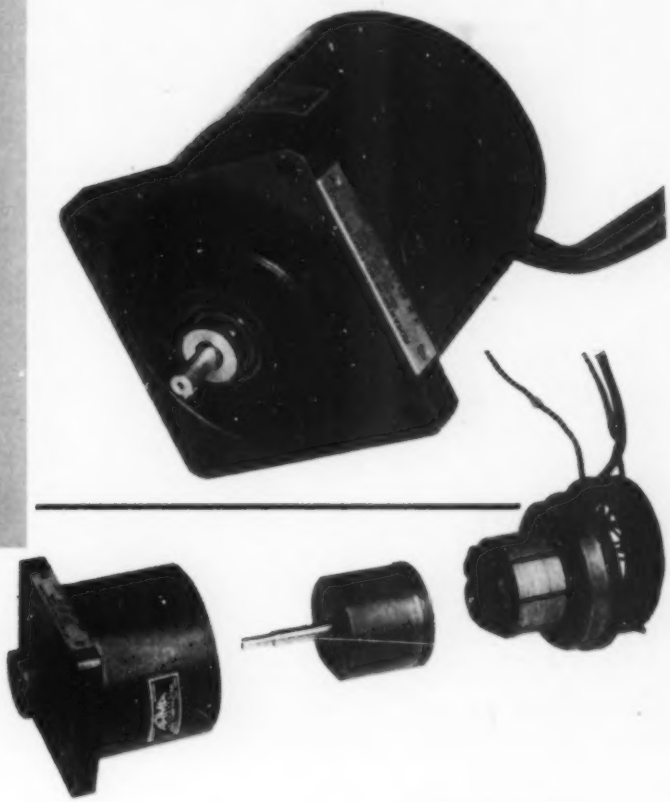
The induction tachometer is similar in appearance to a two-phase squirrel cage induction motor. However, the tachometer is excited on only one phase, and a voltage of line frequency approximately proportional to the speed of shaft rotation is generated on the unexcited or output phase. Its advantages lie in its unique adaptability to alternating current systems and in the high quality obtainable with careful design. Possessing a ruggedness comparable to that of a squirrel cage motor, the drag-cup unit, Fig. 1, can deliver a clean output of high accuracy, free of radio frequency noise and magnetic slot ripple.

The ideal unit has the following characteristics when a sinusoidal excitation is applied to the main winding:

(a) Its output is proportional to shaft speed.

Typical Application Tolerances in High Quality Systems		
Integrator see Fig. 6	Damping see Fig. 7	Velocity Regulator see Fig. 8
H	H	H
H	H	H
H	H	H
H	H	H
H	H	H
H	L	H
H	L	H
H	L	H
H	L	H

Fig. 1—Assembled and exploded views of typical induction generator tachometer. Unit is 5 watt size, rated at 90 volts and 60 cycles. Output is 1 volt per 1,000 rpm with a rated speed of 600 rpm. The output voltage is in-phase with the input voltage within plus or minus 0.5 deg, and the magnitude of the output voltage is within plus or minus 1 percent of the specified value. Harmonic residual is less than 15 millivolts.



of the Tachometer

SIDNEY DAVIS
Research Group, Arma Corporation

(b) At any speed, output voltage is proportional to input voltage.

(c) The phase of the output with respect to the input at any speed is either 0 deg or 180 deg, depending upon the direction of shaft rotation.

(d) The output does not contain any residual voltages.

A schematic representation of an induction tachometer is shown in Fig. 2. Generator excitation is applied to the primary stator winding. The secondary winding is located 90 deg from the primary winding and delivers the output voltage. The rotor is shown as a squirrel cage type.

The instantaneous rotational voltage which is generated in the bars of the rotor is indicated vectorially by the directional symbol on each bar. As a simplifying assumption the rotor bar inductance is neglected. This is a legitimate approximation for well designed tachometers. The bar currents resulting from rotation will therefore be in phase with the generated voltage and a flux field is generated by the rotor along the secondary axis. If the primary axis flux varies sinusoidally at a constant amplitude, a sinusoidal voltage of the same frequency, fixed phase, and proportional to rotational speed is generated in the secondary winding. This represents desired tachometer performance.

Stator leakage reactance and resistance, core losses, and the bar inductance which were neglected in this analysis cause actual tachometer performance to vary from this ideal. These items introduce nonlinearity and a shift in the output phase with increasing generator speed.

Commercially available tachometers may be divided into two classes according to precision. Those having inaccuracies greater than about two percent are classed as low precision and find their greatest application as damping generators in servomechanisms. Those of higher accuracy are used in computer circuits and velocity regulation systems.

The best tachometers available to-

Fig. 2—Schematic diagram of squirrel cage induction tachometer. If the primary flux varies sinusoidally at constant amplitude, a sinusoidal voltage of the same frequency, fixed phase, and proportional to rotational speed is generated in the secondary or output winding.

Fig. 3—An out-of-round rotor causes undesirable coupling between the stator windings and a residual voltage at zero speed. Flux lines such as 1 and 2, set up by the primary coil, link the secondary and induce an output voltage with the rotor stationary.

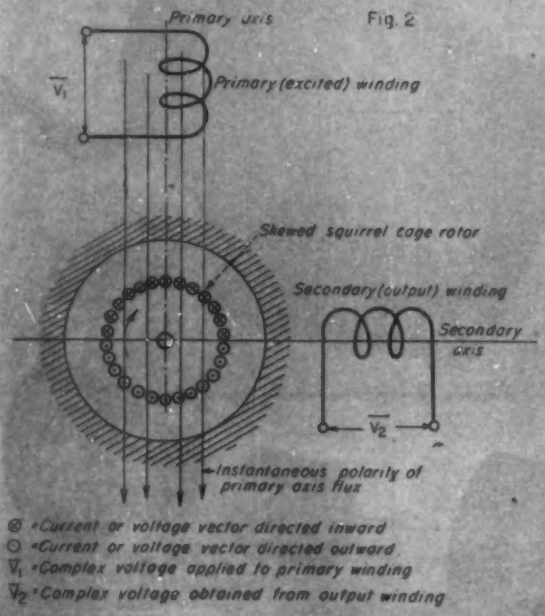
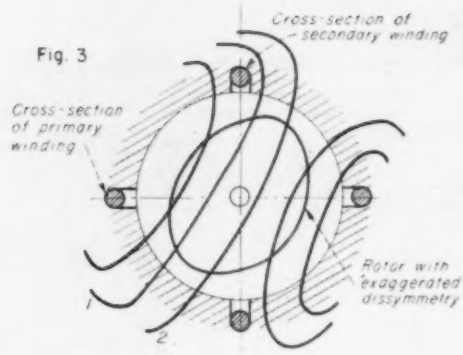


Fig. 2
Primary axis
$\overline{V}_1$
Primary (excited) winding
Skewed squirrel cage rotor
Secondary (output) winding
Secondary axis
$\overline{V}_2$
Instantaneous polarity of primary axis flux
⊗ = Current or voltage vector directed inward
○ = Current or voltage vector directed outward
$\overline{V}_1$ = Complex voltage applied to primary winding
$\overline{V}_2$ = Complex voltage obtained from output winding



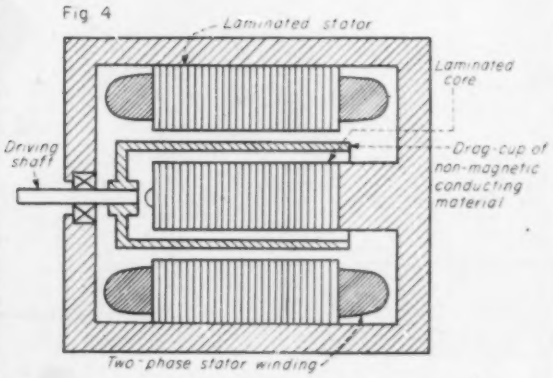


Fig. 4—Cross-sectional view of an induction tachometer. The drag-cup construction reduces the possibility of rotor dissymmetry and therefore reduces the portion of the residual voltage which is dependent on rotor position.

day have accuracies on the order of one part in a thousand. Units of this precision are supplied with standardized output voltage-speed gradients and phase angles, and include temperature compensation.

Less accurate tachometers may be supplied as simple basic components, initially having broad tolerances and requiring adjustment and compensation by the user. These operations are performed through the addition of passive circuit elements, such as temperature sensitive resistors, to the input and output circuits.

While the tachometer's electromagnetic structure is like that of a two-phase motor, it incorporates special design features dictated by accuracy and stability requirements and an attempt to obtain ideal performance. Thus a conventional two-phase motor might serve as a tachometer only in crude applications.

Factors Preventing Ideal Performance

There are three principal types of errors which prevent ideal performance of the induction generator. These are listed in Table I as residual voltage at zero speed, nonlinearity, and voltage gradient and phase angle errors at low speeds.

As shown in Fig. 3, mechanical and magnetic dissymmetries distort the flux paths so that even at zero speed an output voltage is developed. The departure from the ideal geometry of the tachometer, in the form of an out-of-round rotor, causes undesirable coupling between the primary and secondary stator windings as shown by flux lines 1 and 2. This results in an output or residual voltage being induced in the secondary winding even though the rotor is stationary. This zero speed output voltage exerts a deleterious effect on system performance, and manufacturers of these units make every effort to minimize it.

Residual voltage can be conveniently divided into individual components, with each component contributing its characteristic disturbance to a control system, Table I. Thus residual voltage resulting from rotor dissymmetry (which varies with rotor position) is considered separately from residual voltage resulting from stator dissymmetry (which is independent of rotor position). The latter variety can usually be cancelled out by means of decoupling networks between the input and output winding; a technique not applicable to the position sensitive components. The possibility of rotor dissymmetry in a precision tachometer is reduced by using the drag-cup con-

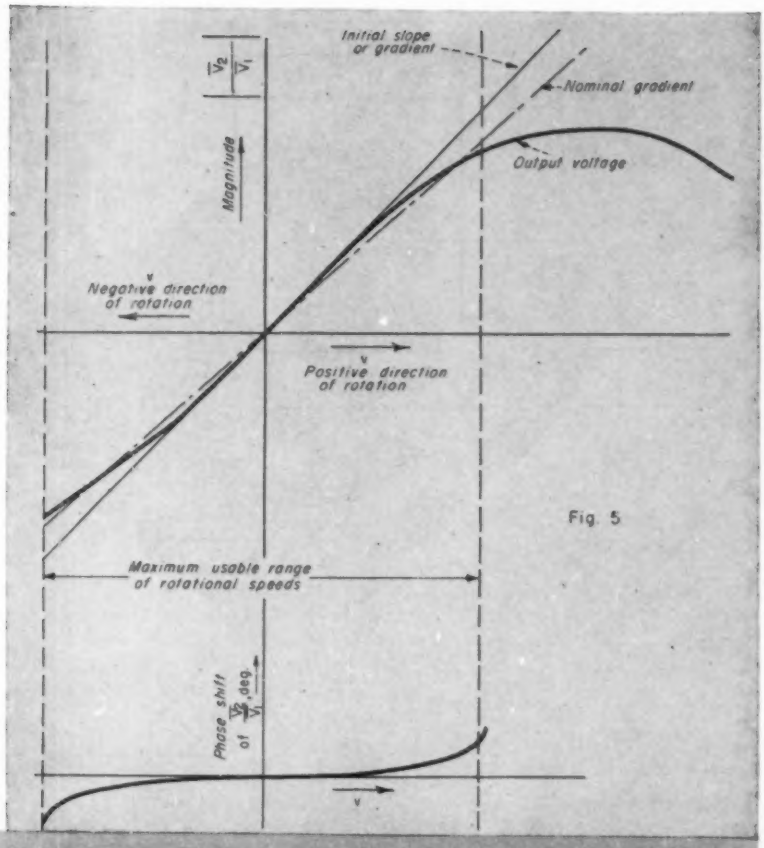


Fig. 5—Typical drag-cup induction generator output voltage characteristic curve. Dotted lines indicate the maximum speed range which can be used without exceeding the allowable nonlinearity for satisfactory performance. The nominal gradient is set by the manufacturer to minimize the effect of nonlinearity.

struction of Fig. 4. While electrically the drag-cup and the squirrel cage are equivalent, a greater degree of rotor symmetry can be obtained with the former.

Depending on its phase angle, the fundamental frequency residual may appear to the external system as an apparent rotational voltage, or as an out-of-phase component tending to cause amplifier saturation. Time harmonics resulting from magnetic circuit nonlinearity tend also to saturate high gain amplifiers. Filters are generally not convenient for the elimination of harmonics, since their characteristics frequently change sharply with any change in line frequency. They also introduce stability problems in closed loop systems.

In addition to residual voltage, the induction tachometer is subject to two other types of errors; nonlinearity, and low speed gradient and phase angle errors. These are most easily defined in terms of the fundamental equation for tachometer speed-sensitive or rotational output voltage. This is in contrast to the residual output which exists independent of rotation.

Generator output voltage can be determined from the following relationship:

$$\frac{\overline{V}_2}{\overline{V}_1} = \frac{\overline{A}v}{1 + \overline{B}v^2} \qquad (1)$$

where

$\overline{V}_1$ = applied voltage on primary winding
$\overline{V}_2$ = rotational voltage induced in secondary winding
($\overline{V}_1$ and $\overline{V}_2$ are fundamental frequency components)
$\overline{A}$ = complex tachometer gradient
$\overline{B}$ = complex nonlinearity coefficient

$$= \frac{\text{actual rpm, } N}{\text{synchronous rpm, } N_s} = \frac{NP}{120f}$$

$$N_s = \frac{120f}{P}$$

P = number of tachometer poles
f = line frequency

At low speeds v is small making the $\overline{B}v^2$ term negligible. Then for practical purposes the right hand side of Eq (1) is $\overline{A}v$, and the voltage output, $\overline{V}_2$, is proportional to speed for constant primary excitation. At synchronous speed $\overline{A}$ is the output voltage per volt input, neglecting $\overline{B}v^2$. It is known as the generator gradient and is the slope of the initial slope or gradient line, Fig. 5. When $\overline{A}$ is a real number, the output voltage and input voltage are in-phase. This is a desirable condition, since the tachometer generator is normally used with other system components, and proper system operation occurs when all the a-c voltages are in-phase.

In an as-manufactured condition, the value of $\overline{A}$ for most units will vary considerably. To adjust $\overline{A}$ to a standard real value, either the manufacturer or the user must add suitable resistor networks to the primary or secondary circuit. Temperature compensation is also frequently included in these networks.

Thus gradient and phase angle errors are introduced by any condition which tends to make $\overline{A}$ deviate from a standard real value.

The $\overline{B}v^2$ term introduces curvature in the output voltage curve, Fig. 5. The value of $\overline{B}$ depends on the leakage impedance of the primary winding. It is usually small enough to be neglected, except in the most exacting applications, if the speed is kept under about one-third synchronous speed.

In high quality units a nominal gradient is set by the manufacturer for minimum nonlinear error over maximum velocity range. This gradient is determined from laboratory measurements on typical samples.

Quality and Tolerances

Either mechanical limitations or an allowable nonlinearity establishes the maximum rotational speed of a component. Percentages of error are determined by the ratio of maximum error voltage to generated output voltage at the maximum speed. Thus quality is defined by the percentage of residual voltage, of nonlinearity, or of gradient error.

The individual tolerances on separate error components is a direct function of the application. While definite values must be established from system requirements, the accompanying table on page 168 broadly suggests tolerances for three typical applications.

Applications

In Fig. 6 is shown a simplified schematic of a typical computer integrator circuit. If the input voltage, E_s, is a function of time, then the output voltage, E_o, is proportional to the time integral of E_s (t) from time t equals O to some time t equals t_o or

$$E_o \propto \int_{t=o}^{t=t_0} E_s(t)\, dt \qquad (2)$$

Thus E_o is proportional to the cross-sectioned area under the curve which represents the variation of E_s (t) with t between t equal O and t equal t_o.

When used as an integrator, the induction generator is driven by an induction motor. The motor is powered by the output of a high-gain amplifier which has as its input the error voltage existing between the output generator voltage, E_t, and the signal input voltage, E_s. The total angular rotation of the generator is transmitted through a gear reducer to the output potentiometer.

If the amplifier gain is very high, ϵ is almost equal to zero and E_s is almost equal to E_t. Then

$$E_t = KN$$

and

$$\int_{t=o}^{t=t_0} E_s(t)dt = \int_{t=o}^{t=t_0} KNdt = K\int_{t=o}^{t=t_0} Ndt$$

but

$$\int_{t=o}^{t=t_0} Ndt$$

is proportional to the total angular rotation, Θ, of the output potentiometer and therefore proportional to E_o so that Eq (2) applies.

This is the most accurate practical type of integrator for a-c voltages that is available for use in computer equipment.

The induction generator is most widely used for velocity damping in conventional position servo systems, Fig. 7. In this case a control transformer is remotely positioned in accordance with the angular input to a synchro generator. The induction generator and induction motor are mechanically connected to the control transformer output shaft, with the generator supplying damping proportional to shaft speed.

An error voltage, which is proportional to the difference between the input angle and the output angle, plus the output voltage of the induction generator, which is proportional to output shaft speed, are transmitted to the motor through a high-gain amplifier. The addition of the damping voltage produces a corrective torque on the output shaft somewhat in advance of the time the torque would otherwise be applied. Servos with tachometer damping will not overshoot when a sudden change in position is required.

A speed regulating system which is similar in basic details to the integrator circuit is shown in Fig. 8. The speed of the induction motor is maintained proportional to the input voltage, E_s, which is tapped from the speed adjusting potentiometer. If the amplifier has a very high gain, ϵ will be almost equal to zero and E_s will be almost equal to E_t. Since the motor speed is proportional to generator output voltage, E_t, it will also be proportional to E_s.

This system gives accurate speed control by the adjustment of a small potentiometer. The quality of the control depends on the regulation of the reference voltage and the accuracy of the tachometer.

If the induction tachometer is excited from a direct current source, a direct current output voltage is developed which is proportional to rotor acceleration. The acceleration voltage (modulated if necessary) can be used to stabilize the more complex servomechanisms.

For maximum quality of performance, certain circuit design principles must be observed. Precision tachom-

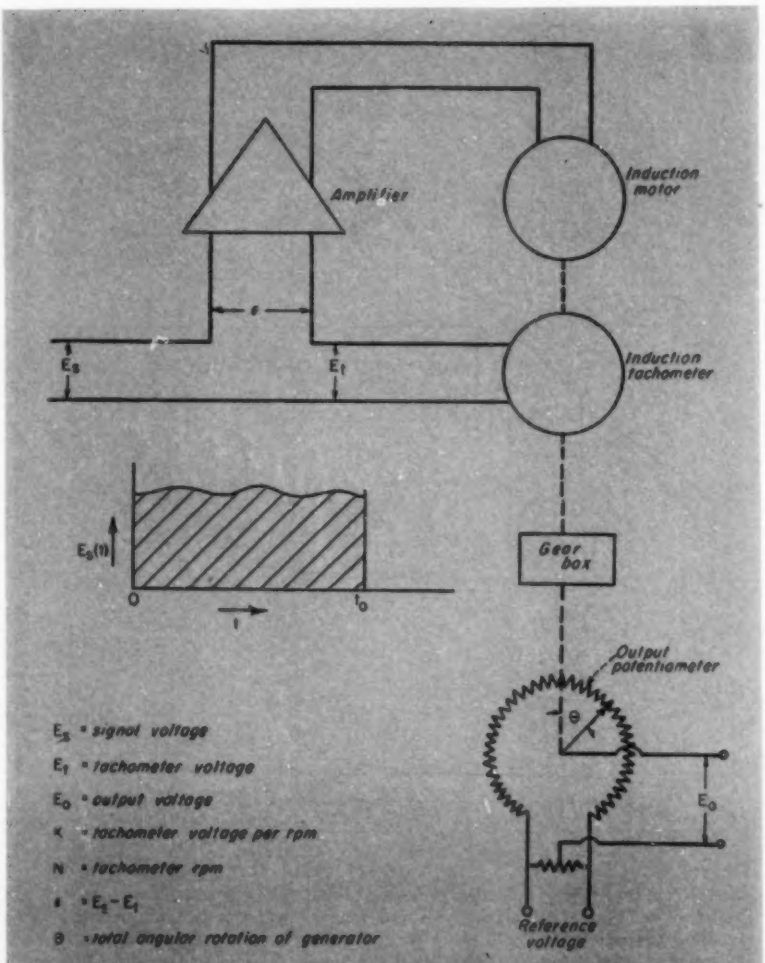


Fig. 6—Simplified schematic of induction generator integrator circuit. With this arrangement the output voltage, E_o, is proportional to the time integral of the input, E_s. The time integral of E_s is represented by the cross-sectioned area under the curve between time t equal 0 and t equal t_o.

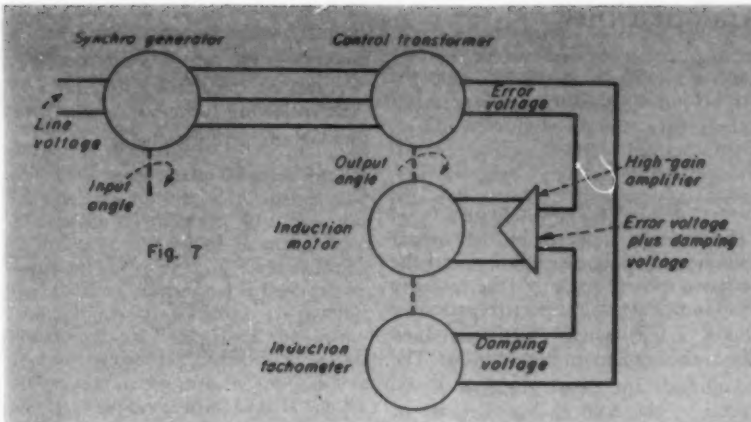


Fig. 7

Fig. 7—Conventional position servo using an induction tachometer for velocity damping. An error voltage is generated proportional to a sudden change in input angle. This error voltage plus the tachometer output voltage are fed into a high-gain amplifier to apply corrective torque to the control transformer.

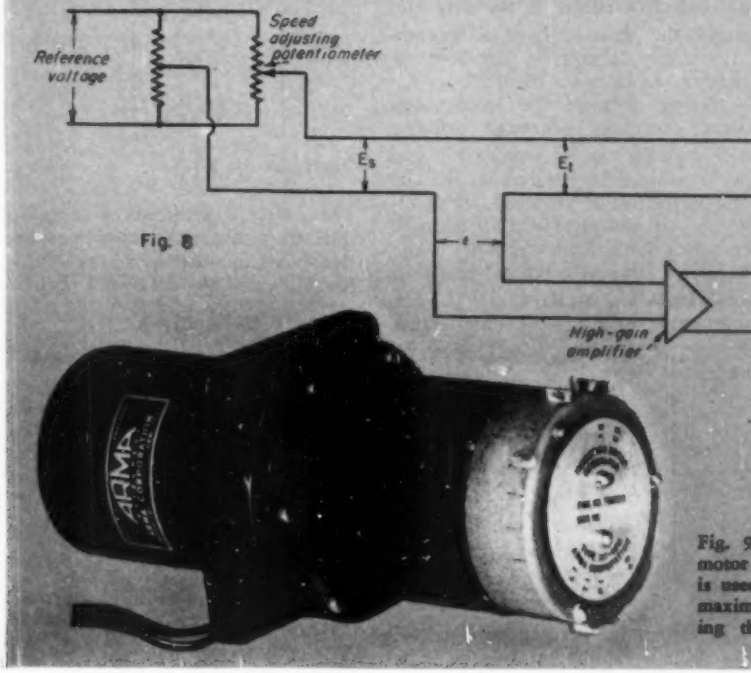


Fig. 8

Fig. 8—Induction tachometer speed regulating system. This is basically similar to the integrator circuit, Fig. 6. With ϵ small, E_t is almost equal to E_s so that E_s is proportional to the motor speed. E_s and consequently motor speed can be set by adjusting the potentiometer.

Fig. 9—Induction generator and induction motor combined in one frame. This type unit is used in integrator circuits which require maximum precision. Backlash is zero, improving the stability of closed loop systems.

eter applications are tricky, and care is needed to avoid introducing errors.

Gear Mesh. To avoid gear chatter and instability in closed loop systems, backlash between the tachometer and its driving motor must be reduced to a minimum. In integrator circuits, which require maximum precision, the motor and tachometer, Fig. 9, are placed on the same shaft.

Load Characteristics. Those design features which make for high tachometer accuracy, at the same time cause high output winding impedance. Normally, final factory adjustment of gradient and phase angle is performed with a standard load across the output terminals. In an instrument, stray cable capacitances may make the effective load substantially different from the apparent (standard) load, thereby disturbing the gradient.

Input Impedance. The drag-cup construction requires a large air-gap, implying low input impedance, large exciting current, and high temperature. Lead impedance between the reference a-c lines and the tachometer terminals must be low so as not to disturb the voltage actually appearing across the primary winding. Also substantial warmup time may be required before characteristics stabilize.

Supply Voltage and Frequency. Deviations from rated values directly affect the magnetic core flux density and consequently its permeability. Because of the directional properties of magnetic iron, the resultant flux axes may shift; introducing residual voltage. In addition, the change in machine parameters resulting from permeability variations has a direct influence on the output gradient and phase. The operating frequency can be shifted with little loss of accuracy, through the use of external equalizer networks, but this requires complicated engineering design. Small changes in the nominal voltage and frequency ratings can be obtained by modifying the manufacturer's values of the standardizing elements.

Drag Torque. Most induction tachometers develop a viscous drag proportional to rotational speed. This may introduce undesirable velocity error in a servo. The system designer should be sure his motor can carry the tachometer load to the required speeds.

Performance Calculations

The application of an induction generator to a specific system involves being able to calculate or approximate such things as: the primary series resistance required to zero the output phase angle, the generator gradient, generator reaction to frequency deviations, and the effect of temperature variation on performance.

These items, as well as others of interest in connection with the performance of an induction generator, can be calculated from the equivalent circuit diagrams shown in Fig. 10 (A) and (B). Symbol designations for these diagrams are given in Table II. Those interested in a simplified derivation of these circuits and in a method for measuring the equivalent circuit constants may refer to Fig. 11.

The circuits of Fig. 10 (A) and (B) are equivalent with the exception that in (*B*) the secondary circuit constants are combined into one circuit parameter, $\overline{Z}_{out}$.

Neglecting the nonlinearity or droop, $\overline{B}$, the performance of an induction generator operating at synchronous speed is characterized by the relationship

$$\frac{\overline{V}_2}{\overline{V}_1} = \overline{A} \qquad (3)$$

where $\overline{A}$ is the gradient of the unit. Thus the generator operating characteristics can be completely determined from the equivalent circuit, Fig. 10 (*B*), by calculating the magnitude and relative phase angle of the ratio $\overline{V}_2/\overline{V}_1$.

The applied voltage to the circuit is represented by the vector $\overline{V}_1$. However, useful flux is produced in the machine according to the voltage $\overline{V}_1'$ because of the drop in the leakage impedance. The effective primary voltage, V_1', can be calculated from the following equations:

$$\frac{\overline{V}_1'}{\overline{V}_1} = \frac{jr_r X_m}{(r_{s1}r_r - X_{ls1}X_m) + j(r_r X_{ls1} + r_{s1}X_m + r_r X_m)} \qquad (4)$$

The voltage induced in the output winding by drag-cup rotation and the relative phase angle of the primary and secondary voltages are represented by $\overline{K}\ a\ \overline{V}_1'$, where $\overline{K}$ is determined from the nomogram Fig. 10 (*C*). The magnitude and phase angle of $\overline{K}$ depend on the ratio r_r/X_m. Because of the inductive effects in the magnetic circuit, the phase angle of $\overline{K}$ becomes increasingly lagging as the resistive element, r_r, becomes smaller.

Having obtained the synchronous output winding generated voltage, $\overline{K}\ a\ \overline{V}_1'$, the output voltage $\overline{V}_2$, can be determined by considering the circuit parameters of the secondary winding and the generator load. If no load, or a negligible load, appears on the secondary (this is the normal operating condition), $\overline{V}_2$ equals $\overline{K}\ a\ V_1'$. For appreciable loading, the drop across the output impedance, $\overline{Z}_{out}$, must be subtracted; where

$$\overline{Z}_{out} = \left[r_{s2} + \frac{a^2 r_r}{1 + \left(\frac{r_r}{X_m}\right)^2} \right] + j \left[X_{ls2} + \frac{a^2 r_r \left(\frac{r_r}{X_m}\right)}{1 + \left(\frac{r_r}{X_m}\right)^2} \right] \qquad (5)$$

In certain applications it is useful to be able to rapidly estimate the effect of small changes in ambient temperature or frequency. In the case of temperature change, the principal effect would be to vary the resistance of the primary winding copper, and the resistance of the cup. The effect on $\overline{V}_1'/\overline{V}_1$ can be calculated from Eq (4). The following formulas, derived from nomogram, give the changes in $\overline{K}$.

Percent change in magnitude of $\overline{K}$

$$= - \frac{\left(\frac{r_r}{X_m}\right)^2}{1 + \left(\frac{r_r}{X_m}\right)^2} \times \text{percent change in } \frac{r_r}{X_m} \qquad (6)$$

$$\text{Change of phase angle in radians} = \frac{1}{100} \times \left[\frac{\left(\frac{r_r}{X_m}\right)}{1 + \left(\frac{r_r}{X_m}\right)^2} \right] \times \text{percent change in } \frac{r_r}{X_m} \qquad (7)$$

In a typical tachometer with r_r/X_m equal to 3, a change in temperature which will increase r_r/X_m by 1 percent will cause the following changes in $\overline{K}$.

$$\text{Change in } \overline{K} = \frac{-(3)^2}{1+3^2} = -\frac{9}{10} = -0.9 \text{ percent}$$

$$\text{Change in angle} = +\frac{1}{100}\left(\frac{3}{1+3^2}\right) = \frac{3}{1000} \text{ radians} = 10.5 \text{ minutes}$$

For actual induction tachometer circuit constants the voltage $\overline{V}_1'$ leads $\overline{V}_1$. This tends to cancel out the lagging phase angle introduced by $\overline{K}$. A common method of obtaining an overall zero phase angle through the unit is

Table II—Symbol Designations for Figs. 10 and 11

- $\overline{V}_1$ = applied voltage on primary winding, nonlinearity neglected ($\overline{B}$ equals 0)
- $\overline{V}_2$ = secondary output voltage
- $\overline{V}_1'$ = effective primary voltage which is generating air-gap flux
- $\overline{K}$ = complex constant representing effect of rotor on primary voltage
- a = ratio of secondary effective turns to primary effective turns
- r_{s1} = resistance of primary winding
- r_{s2} = resistance of secondary winding
- r_s = resistance of one-phase of induction motor
- r_ϕ = phase shift adjusting resistor
- X_{ls1} = leakage reactance of primary winding
- X_{ls2} = leakage reactance of secondary winding
- X_{ls} = leakage reactance of one-phase of induction motor
- r_r = equivalent drag-cup resistance
- r_m = core loss
- X_{lr} = rotor leakage
- X_m = shunting impedance of primary winding
- $\overline{Z}_{out}$ = output impedance of secondary winding
- $\overline{Z}_l$ = secondary load impedance
- v = ratio of actual speed to synchronous speed
- j = $\sqrt{-1}$

to add series resistance in the primary winding until the lead cancels the lag.

The method of performance calculation which has been outlined, and which is used in the following typical example can be used for adapting available components to nonstandard operating conditions. Thus, if only a 60 cycle tachometer is available, and it must be operated on 90 cycles, this technique can be used to make rapid estimates of performance; reducing the required laboratory investigation.

As much information as possible should be obtained from the manufacturer, however, frequently these data are meager or not directly applicable to the applications in question. Operation under unusual conditions of ambient temperature, nonrated voltages, or with nonstandard secondary load are commonly required variations from the manufacturers specifications.

These techniques are also useful if standardization and compensation circuits must be designed to improve the precision of a purchased component. This is frequently necessary.

EXAMPLE. The unit available for this application is a two-phase, four pole, 400 cycle, 115 v, drag-cup servo motor with the following equivalent circuit constants as determined by test:

$r_{s1} = r_{s2} = 100$ ohms
$X_{s1} = X_{s2} = 100$ ohms
$X_m = 400$ ohms
$r_r = 1000$ ohms
$X_{lr} = 0$ (for drag-cup unit)
$a = 1$
$r_m = \infty$ (negligible core losses)

The problem is to evaluate this component for possible applications as an induction generator. The points covered also apply to the case in which a standard drag-cup generator is used under nonstandard conditions.

The load impedance is considered infinite. This condition applies if the output winding feeds the grid of a vacuum tube.

1—What value of series resistance is required in the main winding to zero the output phase?

As indicated, the phase shift con-

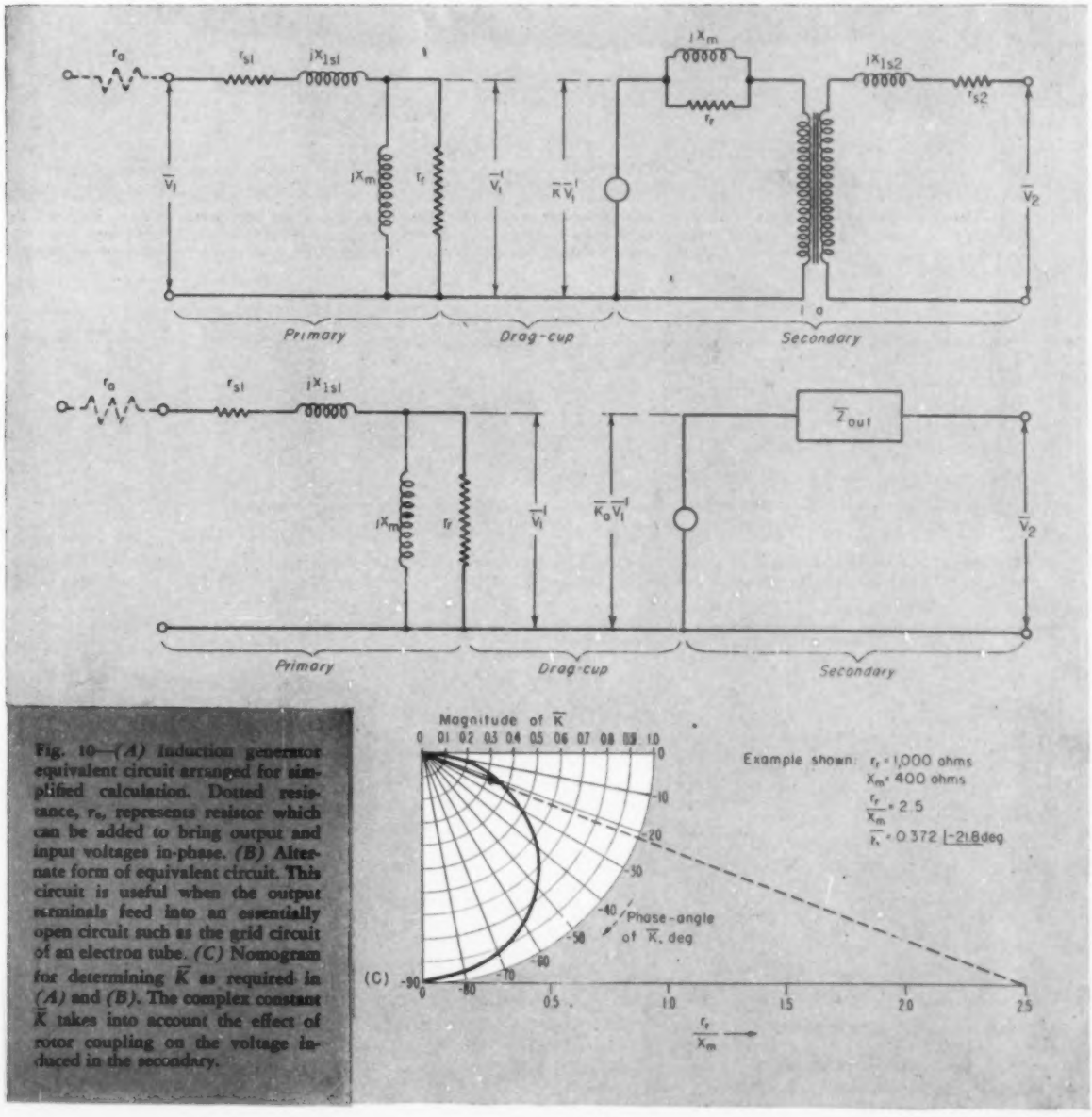
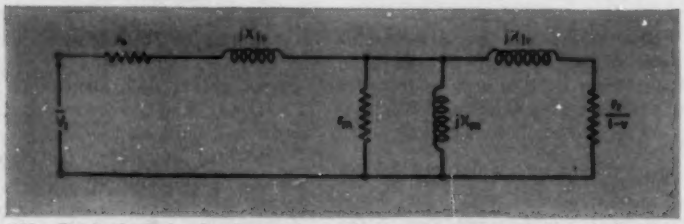
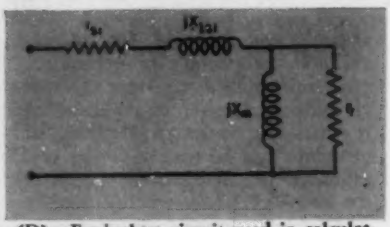


Fig. 10—*(A)* Induction generator equivalent circuit arranged for simplified calculation. Dotted resistance, r_a, represents resistor which can be added to bring output and input voltages in-phase. *(B)* Alternate form of equivalent circuit. This circuit is useful when the output terminals feed into an essentially open circuit such as the grid circuit of an electron tube. *(C)* Nomogram for determining $\bar{K}$ as required in *(A)* and *(B)*. The complex constant $\bar{K}$ takes into account the effect of rotor coupling on the voltage induced in the secondary.

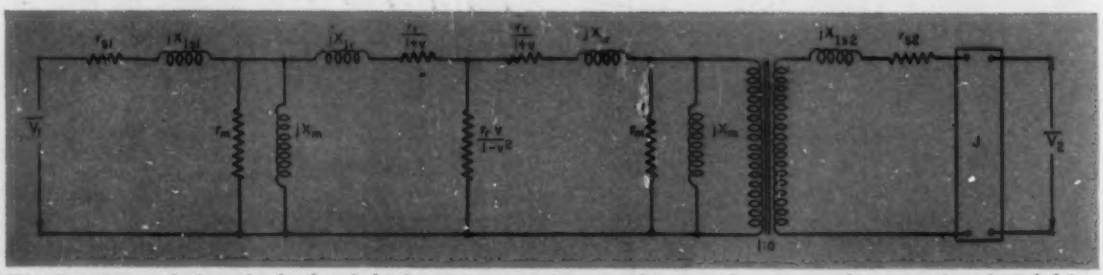
HOW TO FORM EQUIVALENT CIRCUIT AND DETERMINE CIRCUIT CONSTANTS — Fig. 11



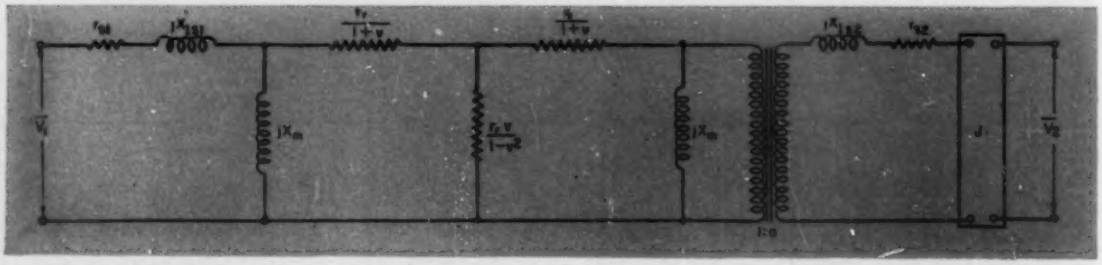
(A)—Equivalent circuit of one phase of a conventional two-phase induction motor. Rotor constants are equivalent values seen from the stator phase. Only one phase of the motor is shown since both phases are identical.



(D)—Equivalent circuit used in calculating primary circuit parameters for condition when the rotor is stationary.



(B)—Complete equivalent circuit of an induction generator tachometer. Constants shown are analogous to those included in the induction motor equivalent circuit except that different values are required for optimum performance. Both phases must be shown since only primary is excited. The turns may differ in the two phases. Element *J* represents ninety degree phase shifter.



(C)—Simplified equivalent circuit of a drag-cup induction generator tachometer. For drag-cup type construction, the rotor leakage, X_{lr}, and the core loss, r_m, can usually be considered negligible without causing a significant error in calculation.

sists of two parts: the phase lead between the voltage actually producing air-gap flux, $\overline{V}_1'$, and the input voltage, $\overline{V}_1$; and the phase lag between $\overline{V}_2$ and the generated output voltage, $\overline{V}_1'$. The lag between $\overline{V}_2$ and $\overline{V}_1'$ can be determined from the nomogram, Fig. 10 (*C*).

$$\frac{r_r}{X_m} = \frac{1000}{400} = 2.5$$

$\overline{K}$ from nomogram = $0.372 \angle -21.8$ deg

Thus, $\overline{V}_2$ lags $\overline{V}_1'$ by 21.8 deg, and an overall zero phase shift can be obtained by adjusting $\overline{V}_1'/\overline{V}_1$ to 21.8 deg leading. This adjustment can be made by inserting a resistor, r_a, in series with the primary winding, Fig. 10 (*A*) and (*B*). This is equivalent to increasing r_{s1}, and Eq (4) becomes:

$$\frac{\overline{V}_1'}{\overline{V}_1} = \frac{jr_r X_m}{Q + R} \qquad (8)$$

where

$$Q = [(r_a + r_{s1})\, r_r - X_{sl1} X_m]$$
$$R = j[r_r X_{sl1} + (r_a + r_{s1})\, X_m + r_r X_m]$$

Since the phase angle of the numerator is 90 deg leading (j term only), $\overline{V}_1'/\overline{V}_1$ will lead by 21.8 deg when the phase angle of the denominator leads by 68.2 degrees. This is true when:

$$\frac{[r_r X_{sl1} + (r_a + r_{s1})\, X_m + r_r X_m]}{[(r_a + r_{s1})\, r_r - X_{sl1} X_m]} =$$
$$\tan (90\text{-}21.8) = \tan 68.2 \text{ deg}$$

Substituting given values for the circuit parameters:

r_a = 186 ohms

2. At what voltage should the primary winding be operated when the unit is used as a generator?

Although the component is rated at 115 v when used as a motor, generator excitation voltage should be about 80 v thereby reducing core saturation and residual harmonics.

3. With the output phase adjusted to zero degrees by the addition of r_a, and the applied voltage 80 v, what

IN THE ANALYSIS of a rotating machine by the equivalent circuit method a complex electromechanical structure (the rotating machine) is replaced by a simple electrical network. Once the equivalent circuit is available, torque, current, power, and other items can be calculated without further reference to the actual machine. Equivalent circuit constants can be predicted by the designer, or accurately measured on actual machines in the laboratory. To save calculation time, machine performance may be determined by making measurements on the stationary arrangement of resistors and inductors constituting the equivalent circuit.

Accordingly, the approach used here for the calculation of performance of the induction generator is based on the equivalent circuit. The accuracy of the results obtained from equivalent circuit analysis for drag-cup units varies from 2 percent to about 15 percent, depending on the design.

The equivalent circuit of a conventional balanced two-phase induction motor is shown in *(A)*. The circuit only includes one phase since the remaining phase is identical. The circuit constants are defined in Table II and include the leakage reactances and resistances of the stator and rotor windings, the air gap reactance, and the resistance equivalent of the core loss.

The equivalent circuit, *(B)*, of an induction generator is not as simple since only one stator winding is excited. Because an output voltage is developed across the other stator winding when the rotor turns, the equivalent circuit must show some coupling between the stator windings through the rotor. This is shown as the resistor $r_r v/1-v^2$. Thus at zero speed (v equal o), the input and output windings are short-circuited and no output is developed.

The circuit constants of a two-phase induction generator are in general exact analogues of the constants of a two-phase induction motor. That is, if the constants of a two-phase motor are known, they may be re-arranged according to *(B)* to give the generator equivalent circuit. The principal differences are in the values required for the constants for optimum performance in either function.

In addition, there are two special features in the generator equivalent circuit. Since, unlike the induction motor, the generator windings frequently have a step-up ratio from primary to secondary to increase the gradient, it is necessary to insert an ideal transformer in the equivalent circuit. Also, analogous to the 90 deg phase shift between the voltages required for the two phases of an induction motor, the nature of an induction generator requires that an ideal 90 deg phase shifter, J, be included in the equivalent circuit. This does not complicate the use of the circuit, since all calculations can be made as if J were omitted. In the final consideration, all currents and voltages to the right of the phase shifter must be advanced 90 deg in time phase. The phase shifter plays no part in the technique for making performance calculations covered here.

For drag-cup tachometers, the leakage of the rotor, X_{1r}, and the core loss, r_m, are usually negligible. For these conditions the equivalent circuit assumes the simplified form shown in *(C)*. The further simplifications shown in Fig. 10 *(A)* and *(B)* can be derived by assuming that the drag-cup resistance, r_r, is shunted across the primary and secondary windings, and that the effect of the rotor on the magnitude and phase-angle of the induced voltage is included in the complex constant $\overline{K}$.

MEASUREMENT OF CIRCUIT CONSTANTS. The values of the constants of an induction generator are such that the approximate methods normally used for measuring the constants of an induction motor will not give satisfactory results. Thus a procedure as outlined here must be followed.

The equivalent circuit constants must be measured for both the primary and secondary windings. The process will be illustrated in the case of the primary. Measurements are best made on an impedance bridge at the rated frequency of operation. The unit must be disassembled during certain phases of the measurement.

With a stationary rotor, the impedance of the primary reduces to the equivalent circuit *(D)*. This total impedance is measured first and then the unit is disassembled, removing the magnetic return path for the stator flux. The winding impedance of the isolated stator will closely approximate r_{s1}, plus jX_{1s1}, since, with the iron core required as a return flux path removed, the main flux corresponding to X_m will be negligible. This method has given accuracy of about 10 percent. The resistance of the primary winding, r_{s1}, will very nearly equal the d-c resistance of the winding. The unit is then reassembled, omitting the cup. This is the same as removing r_r in the equivalent circuit. The measured impedance is then the sum of r_{s1}, jX_{1s1}, and jX_m. Since the first two terms are known, X_m can be calculated. The only unknown value is then r_r, and this can be calculated since the input impedance to the winding has already been measured.

will be the output gradient?

Substitute known values in Eq (8) to determine ratio of $\overline{V}_1'/\overline{V}_1$:

$$\frac{\overline{V}_1'}{\overline{V}_1} = 0.603 \angle 21.8 \text{ deg}$$

and

$$\overline{V}_1' = (0.603 \angle 21.8 \text{ deg})\,\overline{V}_1$$

Since the applied voltage, $\overline{V}_1$, is 80 v,

$$\overline{V}_1' = (0.603 \angle 21.8 \text{ deg}) \times 80 = 48.2 \angle 21.8 \text{ deg}$$

The open circuit synchronous output voltage is given by

$$\overline{V}_2 = \overline{K}\,\overline{V}_1'$$
$$\overline{V}_2 = (0.372 \angle -21.8)\,(48.2 \angle 21.8)$$
$$\overline{V}_2 = 17.97 \angle 0 \text{ deg}$$

The gradient $\overline{A}$ is equal to $\overline{V}_2/\overline{V}_1$ at synchronous speed (v equal 1). Thus

$$\overline{A} = \frac{17.97}{80} = 0.224 \text{ volts per volt input.}$$

The output gradient can also be expressed in terms of volts per 1,000 rpm. The synchronous speed of a four pole, 400 cycle unit is 12,000 rpm, so that:

$$\text{Gradient} = \frac{17.97}{12} = 1.5 \text{ volts per 1,000 rpm}$$

4. If the frequency increases by 5 percent because of poor regulation of the power supply, what will be the effect on the output gradient and phase angle?

For the increased frequency all of the reactances increase by 5 percent since the reactance of an inductance varies directly with frequency. Thus

$$X_{s1} = X_{s2} = 105 \text{ ohms}$$
$$X_m = 420 \text{ ohms}$$

The gradient (volts per 1,000 rpm) for this new condition can be calculated as shown in Part 3. The magnitude of the ratio $\overline{V}_1'/\overline{V}_1$ is obtained by substituting the new circuit constants in Eq 8, while the angle of lead of $\overline{V}_1'/\overline{V}_1$ can be determined from the following relationship:

$$\text{Angle of lead} = 90 - \tan^{-1}\frac{[r_r X_{s1} + (r_s + r_{s1})\,X_m + r_r X_m]}{[(r_s + r_{s1})\,r_r - X_{s1} X_m]} \quad (9)$$

By substitution

$$\frac{\overline{V}_1'}{\overline{V}_1} = 0.609 \angle 20.6 \text{ deg}$$

The changes in $\overline{K}$ can be obtained by using Eqs (6) and (7) which take into account the variation in the ratio r_r/X_m. Since X_m increases by 5 percent, r_r/X_m decreases by 5 percent. Percent change in magnitude of $\overline{K}$

$$= -\left(\frac{(2.5)^2}{1+(2.5)^2}\right)(-5) = 4.31$$

Change in phase angle

$$= +\frac{1}{100}\left(\frac{2.5}{1+(2.5)^2}\right)(-5)$$

$$= -0.01723 \text{ radians}$$

Change in phase angle $= -0.99$ deg

New magnitude of $\overline{K}$

$= (1.0431)\ (0.372) = 0.388$

New phase angle of $\overline{K}$

$= -21.8 - 0.99 = -22.8$ deg

The new open circuit synchronous output voltage is given by:

$$\overline{V}_2 = \overline{K}\overline{V}_1'$$

$$\overline{V}_2 = (0.388 \angle -22.8)\ (0.609 \angle 20.6)\ \overline{V}_1$$

$$\overline{V}_2 = (0.236 \angle -2.2)\ 80 = 18.9 \angle -2.2 \text{ deg}$$

The synchronous speed corresponding to 420 cycles is 12,600 rpm. The gradient in volts per 1,000 rpm is

$$\text{Gradient} = \frac{\overline{V}_2}{N_s/1000} = \frac{18.9}{12.6} \angle -2.2 \text{ deg}$$

Gradient $= 1.5 \angle -2.2$ deg-volts per 1,000 rpm

In this case the frequency variation causes a lagging phase shift of -2.2 deg but does not affect the magnitude of the gradient. Thus only phase shift compensation is required. This can be calculated using the method shown in Part 1. With another component having different circuit constants, magnitude compensation may also be required.

5. At rated voltage and frequency a transformer (which may be assumed ideal) is connected across the tachometer output to increase the gradient to 3 volts per 1,000 rpm. The cable leading from the transformer to the load has a capacitance of 1,200 mmf. How much variation in gradient magnitude and phase is caused by the stray loading?

To increase the gradient from 1.5 volts per 1,000 rpm to 3.0 volts per 1,000 rpm, a transformer with a step-up turns ratio of 3/1.5 or 2 is required.

To evaluate the effect of a 1,200 mmf load, the generator output impedance must be calculated using Eq (5).

$$\overline{Z}_{out} = \left[100 + \frac{1000}{1+(2.5)^2}\right] + j\left[100 + \frac{(1000)\ (2.5)}{1+(2.5)^2}\right]$$

$$\overline{Z}_{out} = 238 + j\,445$$

Because of the step-up ratio the apparent output impedance is:

$$\overline{Z}_{out} \text{ apparent} = (\text{turns ratio})^2\ \overline{Z}_{out}$$

$$\overline{Z}_{out} \text{ apparent} = (2)^2\ (238 + j\,445)$$

$$\overline{Z}_{out} \text{ apparent} = 952 + j\,1780$$

The impedance of 1,200 mmf at 400 cycles is $-j$ 331,000 ohms.

The equivalent output circuit corresponding to rotation at 1,000 rpm is shown in Fig. 12. The voltage developed at the load per 1,000 rpm and consequently the gradient is

$$\text{Gradient} = \left(\frac{-j\,331{,}000}{(952 + j\,1780) - j\,331{,}000}\right)(2)\ (1.5)$$

Gradient $= 3.016 \angle -0.166$ deg-volts per 1,000 rpm

The rise in output voltage from 3 to 3.016 volts is caused by the tendency of the cable capacitance to resonate with the inductance of the source. The effect of cable load on the magnitude and phase angle is appreciable, and must be taken into account in precision applications.

In Fig. 13 is shown a complete diagram of the standardized tachometer showing one possible circuit for cancelling the 400 cycle residual voltage caused by misalignment between the input and output windings.

As indicated previously, this type of analytical approach can also be applied to the problem of temperature compensation. Temperature variations cause gradient changes through their effect on the winding resistances and the resistivity of the drag-cup. These may be calculated in a similar manner to the effect of frequency change in Part 4. Approximate compensation networks can then be devised.

Calculations using the equivalent circuit should be accurate to better than 10 percent, if the circuit parameters are carefully measured.

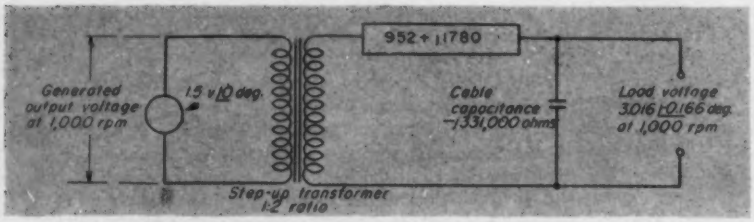

952 + j1780
Generated output voltage at 1,000 rpm
1.5 v ∠0 deg.
Cable capacitance −j331,000 ohms
Load voltage 3.016 ∠−0.166 deg. at 1,000 rpm
Step-up transformer 1:2 ratio

Fig. 12—Equivalent circuit showing effect of cable capacitance on the gradient. Without this capacitance the gradient would be 3∠0 deg-volts per 1,000 rpm. The capacitance causes a shift in magnitude and phase angle to 3.016∠ —0.166 deg-volts per 1,000 rpm.

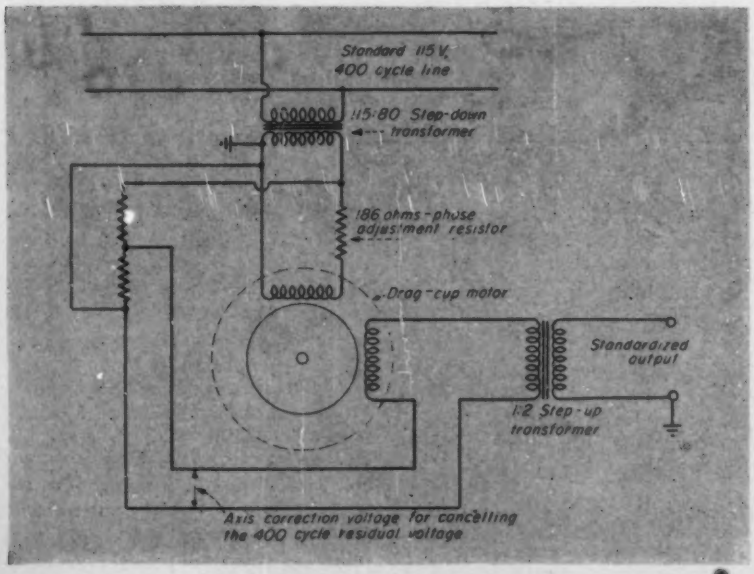

Standard 115 V, 400 cycle line
115:80 Step-down transformer
186 ohms - phase adjustment resistor
Drag-cup motor
Standardized output
1:2 Step-up transformer
Axis correction voltage for cancelling the 400 cycle residual voltage

Fig. 13—Complete diagram of standardized tachometer showing one possible circuit for cancelling the 400 cycle residual voltage caused by misalignment between input and output windings. Phase adjustment resistor is shown in the primary circuit.

How to Evaluate Assembly Tolerances

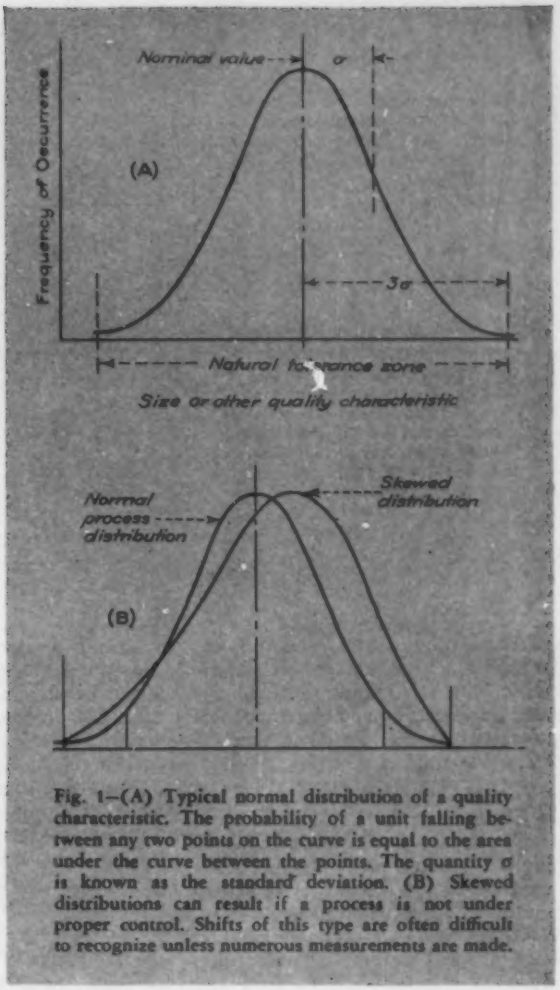


Fig. 1—(A) Typical normal distribution of a quality characteristic. The probability of a unit falling between any two points on the curve is equal to the area under the curve between the points. The quantity σ is known as the standard deviation. (B) Skewed distributions can result if a process is not under proper control. Shifts of this type are often difficult to recognize unless numerous measurements are made.

General rules and examples of how to evaluate the effects of component tolerances on their overall assembly and thus assign more realistic limits. The cases discussed include those of components which are combined into assemblies by simple addition, multiplication and non-linear functions.

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RECENT EXPERIENCE PROVES that it is often possible to assign more reasonable and more economical tolerance values merely by applying some fundamental principles frequently used in statistical quality control. This is particularly true when considering the cumulative effects of component tolerances on the dimensions or performance characteristics of their overall assembly. The most common problem of this type involves determining limits on individual components when the requirements for the assembly as a whole are known. A commonly used technique in such cases has been to allow the tolerance sum to exceed the assembly value by some arbitrary factor and trust to luck to have them come out equal. In fact, when the relationship between components and their assembly is other than simple addition most procedures used today may be even less reliable.

With statistical methods, however, general rules can be derived to cover almost any tolerance problem including cases of multiplication as well as non-linear functions. For these rules to be valid, the dimensions or performance characteristic under study must have frequency distributions as illustrated in Fig. 1(A). This requires having a properly controlled process, i.e., one in which the specifications can be satisfied repeatedly under normal operating conditions. Correctly specified tolerances are defined by the natural tolerance zone shown on the curve. The limits of this zone are plus and minus three sigma where sigma is measured from the nominal value to either of the points of inflection. In accordance with the laws of probability, only one unit out of 370 will then exceed its specifications. The procedures outlined in each of the three problem types that follow assure that assembly tolerances will maintain this same degree of satisfaction. Thus, by recognizing the significance of probability and by assigning values such that 99.7 percent of the assemblies will be satisfactory, the advantages mentioned in the introductory paragraphs can be realized.

If the process is not properly controlled, a skewed distribution such as the one in Fig. 1(B) will result and the procedures that follow are no longer valid; however these procedures give good estimates for distributions only moderately skewed. In such cases, the distribution can usually be corrected by proper use of the techniques presented in texts on statistical control.

Case I. Direct Addition of Component Parts Into an Assembly

An assembly dimension may be the sum of those of several parts, or an

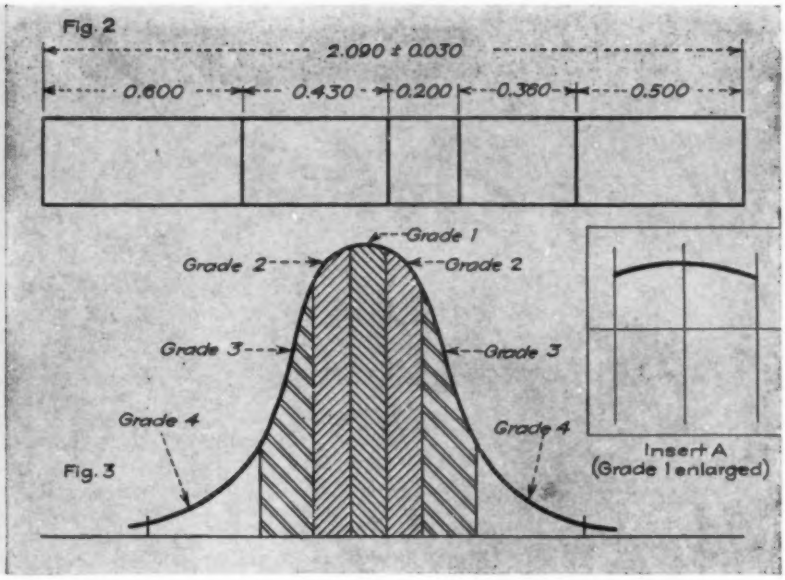


Fig. 2—An example of simple addition of components into an assembly. The problem is to assign individual tolerances such that the overall dimension is 2.090 ± 0.030 inches.

Fig. 3—Vendors using 100 percent inspection may sort parts into several grades—each grade having a different tolerance than the previous one. Insert *A* shows that these grades do not have normal distributions when taken individually and thus Eq (1) does not apply.

electrical resistance may be the sum or difference of component values. If so, the relationship between the total tolerance, T_t, and the component tolerances T_a, T_b, T_c, etc. can be expressed as follows:

$$T_t = \sqrt{T_a^2 + T_b^2 + T_c^2 + \ldots . T_n^2} \quad (1)$$

To illustrate how this equation is used, consider the five parts shown in Fig. 2. The tolerances on these parts must be such that the overall dimension is 2.090 ± 0.030 inches.

Using Eq (1), and assuming that each part will have the same tolerance, T,

$$T = \frac{0.030}{\sqrt{5}} = 0.0134 \text{ in.}$$

This is a more realistic and more economical value than would be obtained by dividing 0.030 by five, and the 2.090 in. dimension still will be within the required limits 99.7 percent of the time.

The above equation also shows that when attempting to reduce an overall assembly tolerance, the effect of reducing the larger values is much greater than that of cutting the smaller ones. For example, assume four quantities which are added together having the following tolerances:

T_a = ±0.004
T_b = ±0.002
T_c = ±0.010
T_d = ±0.006

As defined previously,

$$T_t = \pm \sqrt{0.000156} = \pm 0.0125 \text{ in.}$$

If it is necessary to reduce this value to ± 0.011, it can be done either by making T_c equal to ± 0.008 and having the others as they are, or by reducing T_a to 0.002, T_b to 0.001, T_d to 0.004 and keeping T_c as is. In fact, merely reducing T_b to zero hardly has any effect at all although it undoubtedly would increase costs to a prohibitive level.

When two or more components of an assembly are correlated or related because of the method of manufacture, however, these correlated parts should be considered as a unit com-

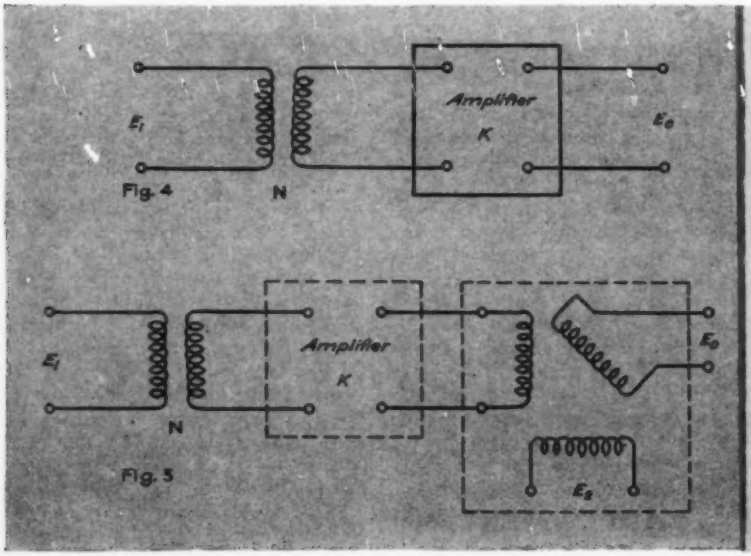


Fig. 4—The output voltage E_o of this circuit is a function of the product of the components.

Fig. 5—Adding a phase-shifting synchro to the circuit of Fig. 4 causes the output voltage to become a non-linear function of the components. As described in the text, a tolerance problem of this type can be broken down to a case of addition plus multiplication.

ponent with one combined tolerance rather than as defined by Eq (1). Such an application would be a 0.30 in. spacer which consists of three 0.10 in. spacers punched consecutively from a large sheet whose tolerance is 0.005. A tolerance of ± 0.015 should be assigned to the 0.30 in. spacer instead of considering the 0.10 in. units individually.

In the event that components are procured from vendors, it is often helpful to consider their methods of inspection. Usually, low cost per unit items are inspected by a statistical sampling plan and the distribution should approach the normal curve of Fig. 1. In such cases, Eq (1) is valid and can be used for combining tolerances. When it is suspected that products are sorted into different quality grades after manufacture, a modification should be used. This approach could apply to cases of high cost units such as precision resistors or a precision machined cylinder. In a typical example the product is manufactured in a properly controlled process. Since in this case the inspection cost is low in comparison to the manufacturing cost, the inspection process might consist of sorting the product into grades according to degree of precision. Fig. 3 illustrates how a product could be sorted into 4 grades of quality to be sold at 4 different prices for different applications. When a product of this type is used as a component in an assembly, it can be shown mathematically that doubling the vendor's specified tolerance before using in Eq (1) makes a good approximation.

Case II Overall Tolerances Affected by Several Components Multiplied Together

When the relationship between the individual components and their assembly can be expressed as a product, the overall tolerance can be expressed as

$$\left(\frac{T_t}{t}\right)^2=\left(\frac{T_a}{a}\right)^2+\left(\frac{T_b}{b}\right)^2+\left(\frac{T_c}{c}\right)^2+\cdots$$

where

t, a, b, c, etc. correspond to the nominal values of the assembly and components respectively and the components and assembly are normally distributed.

In the electrical circuit of Fig. 4, the voltage E_o is required to be 60 volts ± 3 percent with components of the following accuracies:

$E_1 = 40 \pm 0.5$ volts
$N = 2$ to 1 ± 1 percent
$K = 3 \pm 2$ percent

Since $E_o = E_1 N K$, the tolerance relation of Eq (2) is given by

$$\left(\frac{T_{E_o}}{E_o}\right)^2=\left(\frac{T_N}{N}\right)^2+\left(\frac{T_{E_1}}{E_1}\right)^2+\left(\frac{T_K}{K}\right)^2 \qquad (3)$$

$$\left(\frac{T_{E_o}}{60}\right)=(0.01)^2+\left(\frac{0.5}{40}\right)^2+(0.02)^2$$

$$\left(\frac{T_{E_o}}{60}\right)=0.0256,\ T_{E_o}=1.54 \text{ volts}$$

Thus, the output voltage is accurate within 2.56 percent under these conditions and the circuit therefore meets its specifications.

Case III Assemblies of Non-Linear Elements

In complex assemblies, the principles outlined under addition and multiplication can often be expanded to solve tolerance problems. For example, if a phase shifting synchro is added to the output of the electrical circuit in the previous example, as shown in Fig. 5, the new output voltage is given by

$$E_o = E_2 \cos\theta + E_1 N K \sin\theta \qquad (4)$$

where θ refers to the angular relationship of the synchro inputs. To obtain the effect of component tolerance at a certain position, the two terms of this equation are evaluated individually and then combined by the techniques given under the case for simple addition.

Letting

$A = E_2 \cos\theta$
$B = E_1 N K \sin\theta$,

and Δ represent a small, first order change in the mean value, then

$\Delta A = E_2 \sin\theta\,\Delta\theta + \cos\theta\,\Delta E_2$

Dividing by A or its equivalent

$$\frac{\Delta A}{A} = \tan\theta\,\Delta\theta + \Delta E_2/E_2$$

Applying Eq (1),

$$\left(\frac{T_A}{A}\right)^2=(T_\theta \tan\theta)^2+\left(\frac{T_{E_2}}{E_2}\right)^2$$

In a simliar manner

$$\left(\frac{T_B}{B}\right)^2=\left(\frac{T_{E_1}}{E_1}\right)^2+\left(\frac{T_K}{K}\right)^2+\left(\frac{T_N}{N}\right)^2+(T_\theta \cot\theta)^2$$

The tolerance of the total output voltage can now be expressed as follows:

$$T_{E_o} = \sqrt{T_A^2+T_B^2} \qquad (5)$$

Assigning typical values and tolerances to the components,

$E_1 = 40 \pm 0.5$ volts
$N = 2$ to 1 ± 1 percent
$K = 3 \pm 2$ percent
$\theta = 60 \pm 1/4$ degrees (0.00436 radians)
$E_2 = 40 \pm 0.4$ volts

Thus, $E_o = 40 \cos 60 + (40)(0.5)(3) \sin 60$ or $E_o = 20 + 52 = 72$ volts.

From Eq (1),

$$\left(\frac{T_A}{20}\right)^2=(0.00436 \tan 60)^2+(0.01)^2$$

$$\frac{T_A}{20} = 0.0125 = 1.25 \text{ percent}$$

or $T_A = 0.25$ volts.

Also, $\left(\frac{T_B}{52}\right)^2=\left(\frac{0.5}{40}\right)^2+(0.02)^2+(0.01)^2+(0.00436 \cot 60)^2$.

$$\left(\frac{T_B}{52}\right) = 0.0257 = 2.57 \text{ percent}$$

or $T_B = 1.34$ volts

Using Eq (5),

$(T_{E_o})^2 = (T_A)^2+(T_B)^2 = (0.25)^2+(1.34)^2$, or

$T_{E_o} = 1.36$ volts.

The percent variation for the circuit is therefore 1.36 percent, of which nearly all is from the B term. Thus, as discussed under the case of simple addition, the components of B should be considered first if closer control is required on the output voltage.

Painted-on Film Solves Tough Lubrication Problems

TO LUBRICATE SURFACES that must be kept free of oil, a painted-on film of molybdenum disulfide provides a tough load-bearing finish. Such a lubricant-coating, from a fifth to half a thousands thick, puts a lustrous, greasy-feeling but clean, coating on any type surface—plastics, glass, and ceramics.

On bearing parts, the coating carries the load and governs friction, relaxing specifications for machined surfaces. Except in extreme cases, normal clearances remain the same, since the final coating thickness is no greater than normal allowances for oil.

Conventional paint spraying or brushing techniques are used to apply the coating. However the material can also be silk screened onto parts to apply it in irregular patterns.

Most effective use of the coating is in instruments and optical and electronic apparatus where the designer cannot use a liquid that contains volatiles or dry powders. Another application lies in the design of machine tools where some surfaces must be kept clean and cannot be oiled.

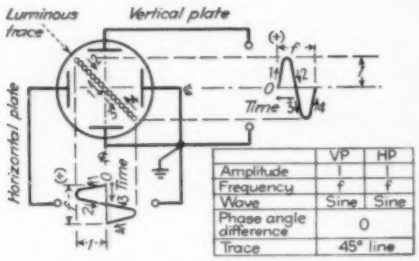
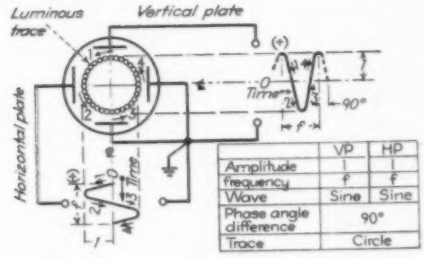
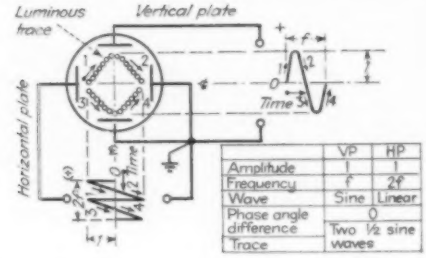
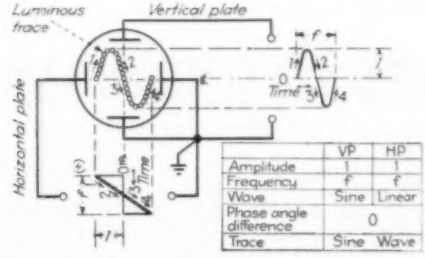
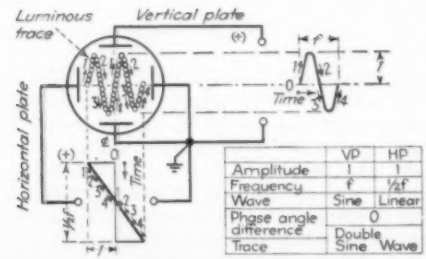
The Lockrey Company, Southhampton, N. Y., has developed a molybdenum disulfide coating which they call Molynamel. They are offering it to users on an experimental basis.

Cathode-Ray Tube Circuits

Type	Input Voltage	Circuit Sketch	Output Trace
Phase Angle Analyzer	Vertical (a-c sine wave) A_1 A_2 B_1 B_2 ← One cycle → Horizontal (a-c sine wave) A_1 A_2 B_1 B_2 ← One cycle →	H = heater, R = resistor, HP = horizontal plate, VP = vertical plate, C = cathode. Input to vertical plates R_{VP}. Input to horizontal plates R_{HP}. HP VP H C G A_1 A_2 Resistor	Luminous trace. Screen
Screen Pattern with Sine Wave Voltage on both Plates	A_1 A_2 B_1 B_2 One cycle	Input. C R. Phase shifting circuit. HP VP H C G A_1 A_2 Resistor	Luminous trace. Screen
Screen Pattern with Double-Frequency Sweep Voltage on Horizontal Plates	Vertical (a-c sine wave) A_1 A_2 B_1 B_2 ← One cycle → Horizontal (linear sweep wave) ← One cycle →	Input to vertical plates R_{VP}. Input to horizontal plates R_{HP}. HP VP H C G A_2 Resistor	Luminous trace. A_1 B_1. Screen
Screen Pattern with Saw-Tooth Sweep Voltage on Horizontal Plates	Vertical (a-c sine wave) A_1 A_2 B_1 B_2 ← One cycle → Horizontal (saw tooth wave) One cycle	Input vertical plates R_{VP}. Input horizontal plates R_{HP}. HP VP H C G A_1 A_2 Resistor	Luminous trace. A_1 B_1. Screen
Screen Pattern with Half-Frequency Sweep Voltage on Horizontal Plates	Vertical (a-c sine wave) A_1 A_2 B_1 B_2 One cycle. One cycle (linear sweep wave) f = frequency	Input vertical plates R_{VP}. Input horizontal plates R_{HP}. HP VP H C G A_1 A_2 Resistor	Luminous trace. A_1 B_1 A_2 B_2. Screen

for Voltage and Current Analysis

RALPH B. IMMEL
Westinghouse Electric Corporation

Operation	Remarks
 VP / HP: Amplitude 1 / 1; Frequency f / f; Wave Sine / Sine; Phase angle difference 0; Trace 45° line	The luminous spot moves in a straight line or trace on the screen when potentials that are in phase and of equal amplitudes and frequencies are applied to the vertical and horizontal deflecting electrodes. If an unknown voltage wave is applied to one set of plates, its phase angle, frequency, and amplitude can be determined when a sine wave is applied to the other set of plates. The resulting trace produced by the voltage waves applied to this and the next circuit shown are known as completed-loop type of Lissajous figures. As the electron beam has a very low inertia and as little or no power is required to deflect it, the cathode-ray tube may be used to study electrical phenomena of radio frequencies.
 VP / HP: Amplitude 1 / 1; Frequency f / f; Wave Sine / Sine; Phase angle difference 90°; Trace Circle	When two sine waves of equal amplitude and frequency, but 90 deg out of phase with each other, are applied to the deflection plates, the electron beam is given a circular motion, producing a circular trace. The potential E_A on the second anode determines the velocity of an electron when it leaves the second anode. The electron velocity in kilometers/second $= 593\sqrt{E_A}$. If the anode potential is 1,200 v, the electron velocity will be approximately 20,000 Km per sec, or 12,000 miles per second. For a tube whose screen is 20 Cm from the deflecting plates, the time for the electron to travel from the anode to the screen will be 1/100,000,000 second.
 VP / HP: Amplitude 1 / 1; Frequency f / 2f; Wave Sine / Linear; Phase angle difference 0; Trace Two ½ sine waves	When a linear sweep wave is applied to the horizontal deflecting plates, the wave applied to the vertical plates will be swept across the screen horizontally at a uniform rate. The resistors R_{VP} and R_{HP} are employed to provide a path to ground for draining off any accumulation of electric charge on the plates. In a practical cathode-ray tube circuit, a d-c biasing means is usually provided so that the electron beam can be centered on the screen when stray electrostatic and magnetic fields disturb the electron stream. It can also be used to center the voltage waves on the tube centerline.
 VP / HP: Amplitude 1 / 1; Frequency f / f; Wave Sine / Linear; Phase angle difference 0; Trace Sine Wave	When the frequency of the linear sweep wave applied to the horizontal plates is the same as that of the vertical plates, the trace will have a wave form similar to that of the voltage applied to the vertical plates. The intensity of the luminous spot or the number of electrons in the beam can be controlled by the potential of the grid. This grid control characteristic is utilized in a television tube. The luminous spot is swept across the screen in a horizontal direction at a rapid and uniform velocity by a saw-tooth wave. At the same time another linear sweep circuit moves the beam in the vertical direction. As a result, a rectangular light pattern appears on the screen. Light and dark areas are formed when the beam is modulated by the grid potential.
 VP / HP: Amplitude 1 / 1; Frequency f / ½f; Wave Sine / Linear; Phase angle difference 0; Trace Double Sine Wave	If the sweep frequency is known, the frequency of the voltage wave applied to the other set of plates can be determined from the trace produced on the screen. The voltage applied to this and the two previous circuits illustrate the effect of the sweep frequency on the resultant luminous trace. The cathode-ray tube is the only device that can sometimes be used to observe some electrical phenomena and is the main element of a cathode-ray oscilloscope. An oscilloscope usualiy consists of a cathode-ray tube, a vertical amplifier, a horizontal amplifier, a sweep oscillator, and a power supply.

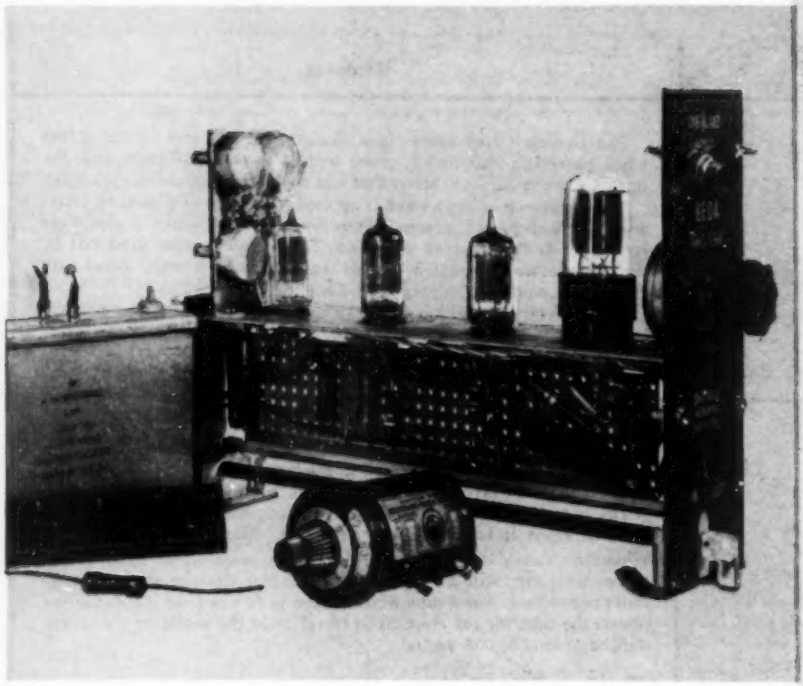


TABLE OF SYMBOLS

(in order of occurrence)

F_g—Gravitational force
M, M′—Masses
k_g—Gravitational constant
r—Distance
F_e—Electrical force
e, e′—Electrical charges
k_e—Dielectric constant
F_m—Magnetic force
m, m′—Magnetic charges
k_m—Magnetic constant
W_g—Gravitational work
W_e—Electrical work
W_m—Magnetic work
V_g—Gravitational potential
V_e—Electrical potential
V_m—Magnetic potential
X—Displacement
B—Mechanical damping
K—Spring constant
F—Force
L—Inductance
R—Resistance
C—Capacitance
Q—Electrical charge
E—Volts
n, n′—Scale factors
t, t_m—Time
$\nabla^2 \phi$—Laplacian of ϕ
T—Temperature
f(t)—Arbitrary function
θ, ϕ, z—Coordinates
Z_n—Impedance
Y_o—Displacement
G—Coulomb-friction factor

In system design and evaluation, analogs offer many advantages from the standpoint of time and cost. Complex problems that would not otherwise be tackled can be accurately solved through the use of analogies that link the various laws of nature. Typical problems solvable with these analogs are systems involving lumped and distributed constants.

Analogous Systems

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R. L. MERRILL
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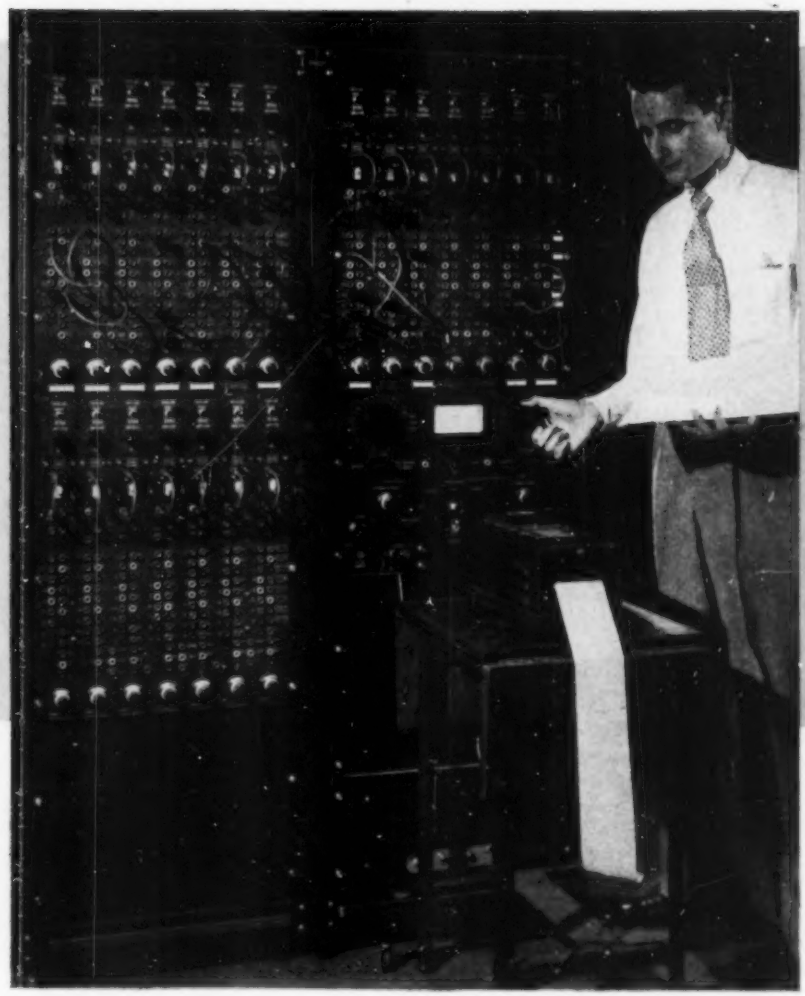
MANY PRESENT-DAY DESIGN PROBLEMS have become so complex that they are difficult if not impossible to solve by ordinary empirical procedures. A disproportionate amount of engineering time and money is therefore expended on extensive calculations, and in tests to prove the assumptions underlying these calculations. One answer to this problem is to make use of the analogies that relate the simple laws of science. These remarkable similarities are a powerful means of increasing the designer's productivity, and can result in better engineering designs at reduced cost.

Analogous engineering systems permit the designer to translate a given problem from one physical system in which design computations are difficult and test models expensive, to another physical system in which low-cost models with continuously variable parameters can be quickly produced and tested. Within the range of operating conditions in which known linear and other laws of design apply, data obtained in the analogous system are applicable in the *original* system. Thus, the dynamic performance of mechanical, acoustic, hydraulic, thermal, magnetic and even complex systems containing components in several of these physical fields, can often be reproduced with simple analogous electrical systems.

Electrical models can be produced at low cost in minimum time, and once assembled, can easily be modified with the many electrical components mass-produced to fill radio, television, industrial control and armed services requirements. It is easier to turn a variable resistance control through one-hundred settings than it is to machine



ELECTRONIC differential analyzer at Battelle Memorial Institute is used for solving differential equations that arise in the analysis of problems in many branches of engineering. It consists of 21 operational amplifiers, together with the necessary precision resistors, capacitors, and potentiometers required to solve equations of approximately the eighth order. The d-c amplifiers are mounted so that they can be removed individually for servicing. By means of suitable switching, the voltage from any point in the computer can be read on the recorder. The meter panel is incorporated into the computer to simplify balancing the amplifiers and checking the plate supply voltages.

in Engineering Design

one-hundred similar mechanical components of varying dimension or mass. And more important, the computational and recording devices now available are designed to accept the ouput signals of voltage and current produced in electrical models, whereas complex sensing and conversion devices are required if equivalent measurements are to be made in mechanical or thermal systems. Many important mathematical manipulations, such as algebraic summation, trigonometric resolution, differentiation, integration and other data-processing steps, can be carried out rapidly with electrical analogs of the mathematical operations.

Analogous Laws of Nature

The creative scientists of past centuries showed great insight into analogies between basic laws of nature. Newton found that the *gravitational force* between two point masses is proportional to the product of the masses, and inversely proportional to the square of the distance between them. Coulomb concluded that the force between two point *electric* charges or between two isolated-point *magnetic* poles, is also proportional to the product of the two quantities and inversely proportional to the square of the distance between them. The striking analogy between these basic laws for three different physical systems is shown by the following relationships:

GRAVITATIONAL:

$$F_g = \frac{MM'}{k_g r^2} \qquad (1a)$$

ELECTRICAL:

$$F_e = \frac{ee'}{k_e r^2} \qquad (1b)$$

MAGNETIC:

$$F_m = \frac{mm'}{k_m r^2} \qquad (1c)$$

Of course, the gravitational force between masses is always attractive, as is the force between unlike polarities; and the force between like electric charges or like magnetic poles is repulsive. Yet the mathematical expressions for these three laws are similar in form.

The existence of similar laws of *force* in static gravitational, electrical, and magnetic fields immediately establishes analogies between many other relations for these fields. For example, the *work* done in separating two adjacent bodies to an infinite distance is obtained by integrating the force over the path they follow:

GRAVITATIONAL: $W_g = \int_{r=r_1}^{r=\infty} F_g dr$

$$= \int_{r=r_1}^{r=\infty} \frac{MM'\,dr}{k_g r^2} = \frac{MM'}{k_g r_1} \qquad (2a)$$

ELECTRICAL:
(for charges of opposite polarity)

$$W_e = \int_{r=r_1}^{r=\infty} F_e dr$$

$$= \int_{r=r_1}^{r=\infty} \frac{ee'_2\,dr}{k_e r} = \frac{ee'}{k_e r_1} \qquad (2b)$$

MAGNETIC:
(for poles of opposite polarity)

$$W_m = \int_{r=r_1}^{r=\infty} F_m dr$$

$$= \int_{r=r_1}^{r=\infty} \frac{mm'_2 dr}{k_m r} = \frac{mm'}{k_m r_1} \qquad (2c)$$

Since the potential at any point in a field is a measure of the *work* done in bringing a unit magnitude from infinity to that point, the preceding analogies can be converted to similar expressions for potential and for expressions derived from potential as follows:

GRAVITATIONAL POTENTIAL:

$$V_g = \frac{M}{k_g r} \qquad (3a)$$

ELECTRICAL POTENTIAL:

$$V_e = \frac{e}{k_e r} \qquad (3b)$$

MAGNETIC POTENTIAL:

$$V_m = \frac{m}{k_m r} \qquad (3c)$$

These expressions hold true only for point magnitudes in the fields, but since they apply for each point magnitude, the effects of distributed quantities can be established by simple integration or superposition.

Analogous Engineering Systems

The above analogies apply only to the fields of static mechanics, electrostatics and magnetostatics. Analogous relations also exist between these and the related fields of heat flow, hydraulics, acoustics and other forms of energy transfer. From the analogies listed in Table I, it is evident that parameters in different physical systems occupy similar positions in the mathematical expressions of the natural laws. Several such examples appear in Table II. In those instances where it might be difficult to write all the equations relating the parameters of a physical system, it is sometimes possible to construct a direct analog of the original system in the model system, simply by replacing each component of the original system with its analogous component in the model.

Using the parameter analogs listed in Table II, it is possible to build up, step-by-step, electrical analogs for very complex physical systems. Each element of the original physical system is replaced by its corresponding element in the analog system. Furthermore, each interconnection, or possible interaction or interdependence in the original system, must be appropriately expressed in the analog system so that the dynamic performance characteristics of the two systems are similar. If the analog truly reproduces the original system, it is not necessary that the engineer be able to write explicit equations for either system (which might be difficult with very complex systems). Instead, it is only necessary that the analog be a true and valid model, and the applied forces and operating boundary conditions be known. The desired forces can then be applied for each design modification, and the system performance established from tests on the analog. The latter data are then translated directly back into terms appropriate to the original system.

Functionally-Analogous Physical Systems

It is not always necessary, and frequently not desirable, to replace every individual element or component of the original system with an equivalent element in the analog system. Instead, the analog models can often be greatly simplified and their usefulness broadened, if they reproduce only the functional operations of the original system. This is particularly appropriate if the performance of the original system can be formulated mathematically. If this is possible, the electrical model can reproduce the mathematical operations implicit in the mathematical formulation of the original system, without regard for the actual nature or elements of that system.

The differential analyzer is a good example. This computer is an electronic model whose carefully-designed amplifiers are adaptable for mathematical operations such as addition, subtraction, integration and differentiation. It can readily handle simultaneous integrodifferential equations (involving both integration and differentiation) of relatively high orders. Multiplication of two variables, arbitrary functions and nonlinear coefficients

Table I—Analogous Laws of Nature

Type of Law	Mechanical Translation	Mechanical Rotation	Thermal Heat-Flow	Hydraulic Mass Flow	Magnetic Circuits	Acoustic Systems	Electric Circuits
Force between point magnitudes	$F_g = \frac{MM1}{K_g r^2}$				$F_m = \frac{mm1}{K_m r^2}$		$F_e = \frac{ee1}{K_e r^2}$
Static equilibrium of forces at a point	$\Sigma F_p = O$	$\Sigma T_p = O$	Law of conservation of energy	Law of conservation of mass	Flux lines are continuous		$\Sigma I_p = O$
Dynamic response to applied force	$F = Ma$	$T = J\alpha$				$p = M_a\ddot{x}$	$E = L\frac{dI}{dt}$
$A = BC$	$F = C^{-1}S$	$T = C_R{}^{-1}\theta$	$Q = AV$	$Q = AV$	$MMF = \mathcal{R}\phi$		$E = IR$
$A = B^2C$	$\frac{1}{2}Mv^2$	$\frac{1}{2}J\omega^2$				$\frac{1}{2}M_a\dot{x}^2$	RI^2

Table II—Analogous Parameters in Different Physical Systems

Type of Parameter	Mechanical Translation	Mechanical Rotation	Thermal Heat-Flow	Hydraulic Fluid-Flow	Magnetic Fields and Circuits	Acoustic Systems	Electric	Electric	Electric	Electric
Applied Force	F	T	T	p	MMF $\mathfrak{F}$	Pressure p	E EMF, volts	I Current, amp	dE dt volts/sec	dI/dt amps/sec
Inertial	M	J Polar Moment of Inertia				Acoustical Inertance M_a	L Inductance, henries	$\Gamma = L^{-1}$ Inverse Inductance	L Inductance, henries	$\Gamma = L^{-1}$ Inverse Inductance
Elastance	C_M Compliance	C_R Rotational Compliance	Thermal Capacity	Compressibility		Acoustic Capacitance C_a	$S = C^{-1}$ Elastance, darafs	C Capacitance, farads	$S = C^{-1}$ Elastance, darafs	C Capacitance, farads
Frictional Dissipative	B Translational Resistance	Rotational Resistance	Thermal Resistivity	Hydraulic Resistivity	Reluctance $\mathfrak{R}$	Acoustic Resistivity r_a	R Electrical Resistance, ohms	$G = R^{-1}$ Electrical Conductance, mhos	R Electrical Resistance, ohms	$G = R^{-1}$ Electrical Conductance, mhos
Momentum	$M\frac{ds}{dt}$	$J\frac{d\theta}{dt}$				$M_a c$	LI	ΓE	$L\frac{dI}{dt}$	$\Gamma\frac{dE}{dt}$
Kinetic Energy	$\frac{1}{2}M\left(\frac{ds}{dt}\right)^2$	$\frac{1}{2}J\left(\frac{d\theta}{dt}\right)^2$				$\frac{1}{2}M_a c^2$	$\frac{1}{2}LI^2$	$\frac{1}{2}\Gamma E^2$	$\frac{1}{2}L\left(\frac{dI}{dt}\right)^2$	$\frac{1}{2}L\left(\frac{dI}{dt}\right)^2$
Potential Energy	Ms					$M_a x$	LQ	$\Gamma\int E dt$	LI	ΓE
Power	Fv	$T\omega$	$Q_h T$	$Q_F p$	MMF x ϕ	pc	EI	EI	$\frac{dE}{dt}\frac{dI}{dt}$	$\frac{dE}{dt}\frac{dI}{dt}$
Force Impulse	$\int F dt$	$\int T dt$	$\int T dt$	$\int p dt$	$\int \mathfrak{F} dt$	$\int p dt$	$\int E dt$	$\int I dt$	E	I
Displacement	s	θ				Acoustic Displacement x	$Q = \int I dt$ Electric Charge, coulombs	$\int E dt$ Voltage Impulse, volt/sec	I Electric Current, amp	E Voltage Drop, volts
Velocity	$\frac{ds}{dt} = v$	$\frac{d\theta}{dt} = \omega$	$Q_h \frac{Btu}{sec}$	$Q_F \frac{quantity}{sec}$	ϕ flux	$\frac{dx}{dt} = c$	$I = \frac{dQ}{dt}$ Current, amp = $\frac{coulombs}{sec}$	E Voltage, volts	$\frac{dI}{dt}$ Rate of Change of Current, amp/sec	$\frac{dE}{dt}$ Rate of Change of Voltage, volts/sec
Acceleration	$\frac{d^2s}{dt^2} = a$	$\alpha = \frac{d^2\theta}{dt^2}$				$\frac{d^2x}{dt^2}$	$\frac{dI}{dt} = \frac{d^2Q}{dt^2}$ amp/sec	$\frac{dE}{dt}$ volts/sec	$\frac{d^2I}{dt^2}$ amp/sec^2	$\frac{d^2E}{dt^2}$ volts/sec^2

or parameters can be introduced with specially-designed analyzer elements. Thus, any physical system whose functions can be analyzed as a group of mathematical operations of these types can be simulated by the differential analyzer. When suitable reconnections are made between functional components and the controls properly adjusted, the same differential analyzer will handle successively a multitude of different physical systems or design problems.

Another way of approaching this subject is to recognize that different physical systems whose operations are describable by integrodifferential equations of the same form are of necessity functionally similar, and therefore representable in the same differential analyzer model. Thus, a single differential analyzer can be set up to handle three simultaneous second-order equations with constant coefficients, and used repeatedly, without changing internal connections, on problems from any engineering system whose performance can be described by such equations. Changes in the values of single elements or groups of elements in the engineering system can be reproduced simply by varying the appropriate potentiometers in the differential analyzer. Initial or boundary conditions are set as desired before the appropriate force functions are applied to the analyzer. Sometimes curve-drawing instruments or cameras photographing cathode-ray screens are used to record the applied force functions and the response of the systems.

Designers familiar with the differential or integral equations for their engineering systems find that even a simple differential analyzer can be very useful as a companion to the slide rule and calculating machines commonly used. Accuracies of one percent or better are obtainable in most cases and are quite adequate, considering the accuracy of the design assumptions and the designer's knowledge of engineering materials. Computations for typical system arrangements can be completed in a few minutes and do not require the lengthy manual calculations commonly used in engineering design. The references listed at the end of this article are just a few of the many authoritative sources of additional information on the equations for such physical systems, their analysis and application.

Analogous Systems as Components of Engineering Systems

The designer of complex systems can profit by recognizing and applying another basic principle of design. In an engineering system containing many functional elements or groups of components, certain chains of functions are difficult to design or produce while in the original physical system. In such instances, it may be advantageous to replace these operational functions in the original physical system with equivalent functional operations in an analogous system offering advantages of simplicity and reliability in design and operation. For example, a complex mechanical aircraft-control system can be miniaturized and improved if, at a suitable point, the mechanical system operation is converted into an equivalent function of an electrical or hydraulic system. This requires an adequate transducer or conversion device that faithfully translates the mechanical function into an appropriate analogue signal. The difficult transmission, computational or other design functions are then carried out in the analogous system. In a final step, the electrical or hydraulic response functions are translated back into the original physical system by a suitable transducer. This principle can be extended to industrial control systems and other applications, resulting in significant cost reductions, increases in operational speed and accuracy, and reductions in the over-all costs and size of equipment.

Electric Analogs for Lumped-Constant Problems

If a problem in dynamics is represented by a linear second-order differential equation with constant coefficients and an electric analogy is to be used, an electric circuit with the same general equation has to be found. In some instances, however, the electric analog is not the only solution and, as in some mechanical systems, an acoustic analog may have certain advantages. But, in general, the widespread knowledge of electric circuit theory and measurement techniques, coupled with the availability of high-quality variable electric components such as inductors, capacitors and resistors, makes the electric analogy most desirable.

To see in detail how an electric analog of a system is obtained, consider the mechanical system shown in Fig. 1(a). It consists of a mass M, of 38.6 lb connected to a fixed reference by a spring K, whose constant is 10 lb per inch. A driving force, $F(t) = 10 \cos \alpha t$, is applied to the mass M, and there is a damping force, B, equal to 5 lb per in. per second. The equation for displacement x in this system is:

$$M \frac{d^2x}{dt^2} + B \frac{dx}{dt} + Kx = F \cos \alpha t \quad (4)$$

or, dividing by M

$$\frac{d^2x}{dt^2} + \frac{B}{M} \frac{dx}{dt} + \frac{Kx}{M} = \frac{F}{M} \cos \alpha t \quad (5)$$

The analogous electrical system is shown in Fig. 1(b) in which inductance L, capacitance C and resistance R are connected in series with an alternating current source. Its equation is therefore:

$$L \frac{d^2Q}{dt_m^2} + R \frac{dQ}{dt_m} + \frac{Q}{C} = E \cos \omega t_m \quad (6)$$

where t_m is the time and Q the charge in the electrical system. Dividing by L

$$\frac{d^2Q}{dt_m^2} + \frac{R}{L} \frac{dQ}{dt_m} + \frac{Q}{CL} = \frac{E}{L} \cos \omega t_m \quad (7)$$

The most direct design procedure is to equate the corresponding coefficients in the two equations (1). In this case, charge Q becomes analogous to displacement x, inductance L to mass M, resistance R to damping B, capacitance C to compliance $1/K$, and voltage E to force F. Equating coefficients gives the following set of equations:

$$\frac{R}{L} = \frac{B}{M} ; \frac{1}{CL} = \frac{K}{M} ; \frac{E}{L} = \frac{F}{M} \quad (8)$$

There being four electrical parameters in these three equations, only one can be chosen arbitrarily. In this analog $t_m = t$ and $\omega = \alpha$. Therefore, velocity is

$$\frac{dx}{dt} = \frac{dQ}{dt} = I = \frac{E}{R}$$

and acceleration is

$$\frac{d^2x}{dt^2} = \frac{d^2Q}{dt^2} = \frac{dI}{dt} = \frac{E}{L}$$

Choosing E such that 100 v equals 10 lb,

$$L = \frac{EM}{F} = \frac{100 \times 38.6}{10 \times 386} = 1.0 \text{ henry}$$

($M = W/g$ where g is the acceleration due to gravity or 386 lb-in./sec^2)

$$C = \frac{M}{KL} = \frac{38.6}{386 \times 10 \times 1} = 0.01\mu = 10{,}000\ m\mu$$

$$R = \frac{BL}{M} = \frac{5 \times 386 \times 1}{38.6} = 50 \text{ ohms}$$

This analogy is perfectly valid and useful, but it has several disadvantages. The capacitance value of 10,000 micro-

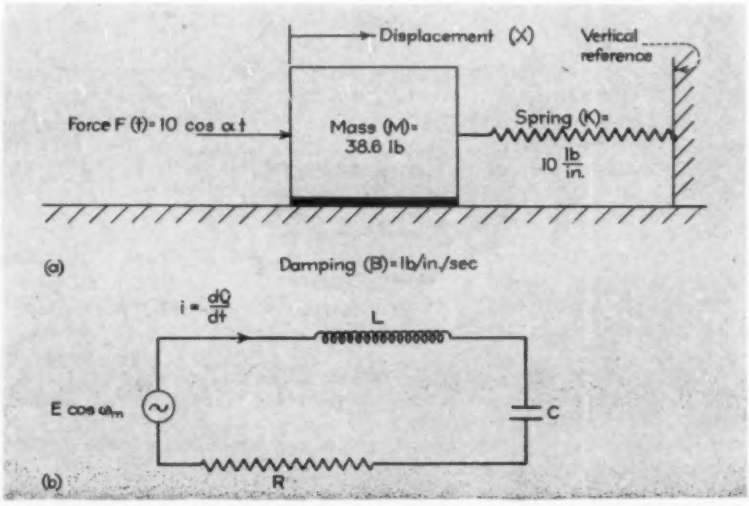


Fig. 1—Mechanical system (a) with mass M working against spring K and friction B is converted to analog (b). Q is analogous to x, L to M, R to B and E to F.

farads is high and therefore might be difficult to obtain in such a large size. The value of C could be reduced by increasing L, but this is already 1.0 henry, and increasing it would make it more difficult to obtain.

Another disadvantage is that the frequency of the electric circuit equals that of the mechanical circuit. If the mechanical frequency is very low, it might be convenient to speed up the solution. On the other hand, if the mechanical frequency were relatively high, say 2,000 cps, it would not be convenient to record it on available graphic recording instruments.

One solution is to use appropriate scale changes in time and displacement. Consider the mechanical system just discussed with the addition of two scale factors n_1 and n. To change the time scale, let $t = n_1 t_m$. Thus, if $n_1 = 10$, then one second in the mechanical system is only one-tenth of a second in the electrical system. The value of n can be arbitrarily chosen as a dimensional constant and used to change the displacement scale; ie, $x = nQ$. Thus:

$$\frac{dx}{dt} = \frac{n dQ}{dt} = \frac{n dQ}{dt_m}\frac{dt_m}{dt} = \frac{n}{n_1}\frac{dQ}{dt_m}$$

$$\frac{d^2x}{dt^2} = \frac{n}{n_1}\frac{d}{dt}\left(\frac{dQ}{dt_m}\right) =$$

$$\frac{n}{n_1}\frac{d^2Q}{dt_m^2}\frac{dt_m}{dt} = \frac{n}{n_1^2}\frac{d^2Q}{dt_m^2}$$

Eq (5) then becomes

$$\frac{n}{n_1^2}\frac{d^2Q}{dt_m^2} + \frac{n}{n_1}\frac{B}{M}\frac{dQ}{dt_m} +$$

$$\frac{KnQ}{M} = \frac{F}{M}\cos n\alpha' \text{ .}$$

or $$\frac{d^2Q}{dt_m^2} + n_1\frac{B}{M}\frac{dQ}{dt_m} +$$

$$\frac{n_1^2 KQ}{M} = \frac{n_1^2}{n}\frac{F}{M}\cos n_1\alpha t_m \qquad (9)$$

A comparison of coefficients in Eqs (9) and (7) gives:

$$\frac{R}{L} = \frac{n_1 B}{M}\text{ ; }\frac{1}{CL} = n_1^2\frac{K}{M}\text{ ;}$$

$$\frac{E}{L} = \frac{n_1^2}{n}\frac{F}{M}\text{ ; }\omega = n_1\alpha \qquad (10)$$

There are now six parameters (R, L, C, E, ω, n) and only four equations so that two parameters can be chosen arbitrarily. This permits more flexibility in the choice of components, as can be seen below. Again letting 100 volts equal 10 lb, and making

$n_1 = 100$ and $n = 10{,}000$

$$L = \frac{nEM}{n_1^2 F} = \frac{10^4 \times 100 \times 38.6}{386 \times 10^4 \times 10}$$

$$= 1.0 \text{ henry}$$

$$C = \frac{M}{n_1^2 KL} = \frac{38.6}{386 \times 10^4 \times 10 \times 1.0}$$

$$= 1.0\ m\mu$$

$$R = \frac{n_1 LB}{M} = \frac{100 \times 1.0 \times 386 \times 5}{38.6}$$

$$= 5{,}000 \text{ ohms}$$

Thus, by means of the scale changes, the value of capacitance has been reduced to one microfarad, which is more workable than the value calculated above.

This analog method can be extended to mechanical systems having more degrees of freedom and to other systems such as acoustic and rotational-mechanical systems. The value of such a method becomes apparent when considering the problem of designing the spring in the foregoing example for optimum performance under varying applied forces. It is much easier and cheaper to vary the electrical parameters than their respective mechanical counterparts.

Electric Analogs for Distributed-Constant Systems

Many distributed-constant systems can be approximated by electrical networks. An example might be that of determining the forces produced in a long coiled spring subjected to cyclic or impact driving forces. The conventional mathematical solution of this problem, while possible, is long and involved, especially if such effects as clashing of adjacent coils is considered.

The analog of the system can be determined in the following way: Consider the spring to be composed of a series of lumped masses and of massless springs connected in series, and that there is damping associated with each mass. In the mechanical schematic of the spring shown in Fig. 2(a), each section of the spring (to be represented) is similar to the mechanical problem of Fig. 1(a). The analog for each section is therefore an inductance, capacitance and resistance element connected in series.

The electric network is shown in

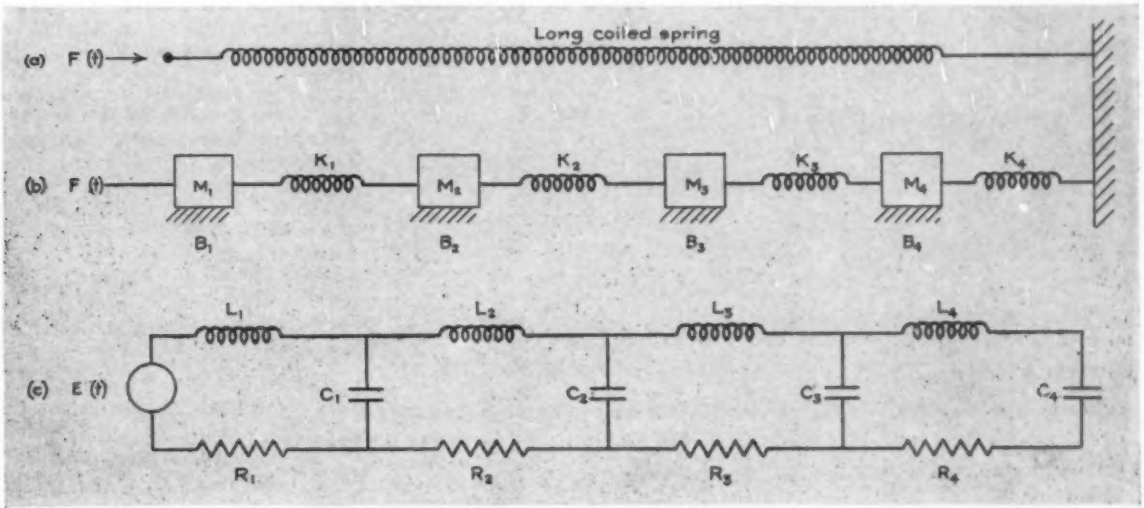


Fig. 2—Distributed-constant system such as long coiled spring (a) can be considered as a series of lumped masses (b) subjected to various forces. Conversion to analog (c) results in four sections, each containing an inductance, capacitance and resistance.

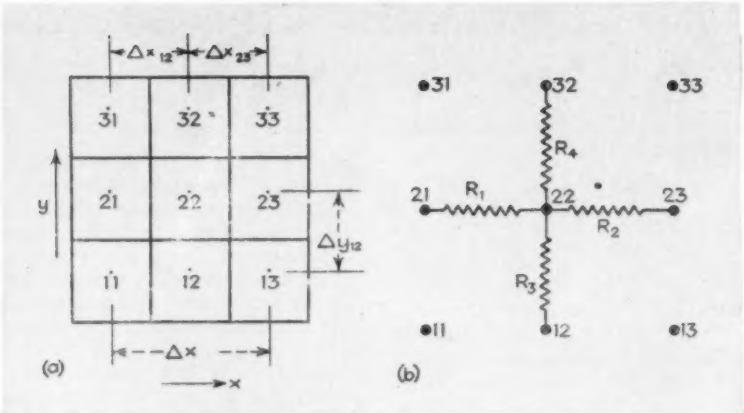


Fig. 3—Partial differential equation of Laplace's relationship and equivalent net (a) can be solved with analog network (b) composed of four resistances connected to common point. Sum of the currents at point 22 must be zero.

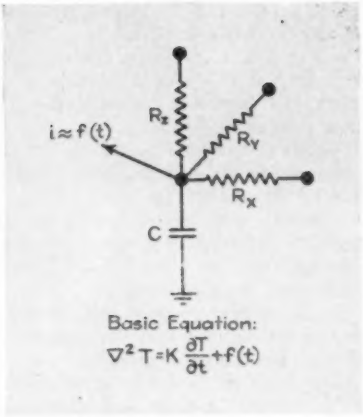


Fig. 4—Transient heat-flow equation involving partial differential with left side represented by three-dimensional network.

Fig. 2(b). Each succeeding section is coupled to the preceding one by a massless spring represented by C. The number of sections determines the accuracy of the solution, and it has been determined experimentally that ten or fewer sections are sufficiently accurate for most engineering problems. More than ten sections improve the accuracy, but also increase the overall expense.

Clashing of adjacent coils can be simulated in the electrical network by a nonlinear device consisting of diodes which limit the electrical displacement of each section when it reaches a value equal to that of its neighbor (2). The spring can thus be subjected to cyclic or impact forces of any type, and the effect of loading, clashing and resonance studied.

Analogs for Partial Differential Equations

Many problems in physics and engineering are specified by partial differential equations, e.g., heat flow, fluid flow and stress problems, and some of these can be approximated by electric networks. To see how a network is set up to represent a partial differential equation, consider Laplace's equation, $\nabla^2\phi = 0$. In cartesian coordinates, this becomes (3)

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0 \qquad (11)$$

Referring to the net in Fig. 3(a) and noting increments Δx, Δx_{12} and Δx_{23}

$$\frac{\partial \phi}{\partial x_{12}} \approx \frac{\phi_{22} - \phi_{21}}{\Delta x_{12}} \qquad (12)$$

$$\frac{\partial \phi}{\partial x_{23}} \approx \frac{\phi_{23} - \phi_{22}}{\Delta x_{23}} \qquad (13)$$

$$\frac{\partial^2 \phi}{\partial x^2} \approx \frac{\phi_{23} - \phi_{22}}{\Delta x\, \Delta x_{23}} - \frac{\phi_{22} - \phi_{21}}{\Delta x\, \Delta x_{12}} \qquad (14)$$

and similarly

$$\frac{\partial^2 \phi}{\partial y^2} \approx \frac{\phi_{32} - \phi_{22}}{\Delta y\, \Delta y_{32}} - \frac{\phi_{22} - \phi_{12}}{\Delta y\, \Delta y_{21}} \qquad (15)$$

Thus, by equating and substituting expressions

$$\nabla^2 \phi = \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2}$$

$$= \frac{\phi_{23} - \phi_{22}}{\Delta x\, \Delta x_{23}} - \frac{\phi_{22} - \phi_{21}}{\Delta x\, \Delta x_{12}} +$$

$$\frac{\phi_{32} - \phi_{22}}{\Delta y\, \Delta y_{32}} - \frac{\phi_{22} - \phi_{12}}{\Delta y\, \Delta y_{21}} = 0 \qquad (16)$$

An electrical equation of the same general form is composed of four resistors connected to a common point as in Fig. 3(b). The sum of the currents at point 22 must be zero by Kirchoff's Law. Hence,

$$\frac{E_{23} - E_{22}}{R_2} - \frac{E_{22} - E_{21}}{R_1} +$$

$$\frac{E_{32} - E_{22}}{R_4} - \frac{E_{22} - E_{12}}{R_3} = 0 \qquad (17)$$

Eqs. (16) and (17) are analogous with

$$E_{23} - E_{22} \approx \phi_{23} - \phi_{22}$$
$$E_{22} - E_{21} \approx \phi_{22} - \phi_{21}$$
$$E_{32} - E_{22} \approx \phi_{32} - \phi_{22}$$
$$E_{22} - E_{12} \approx \phi_{22} - \phi_{12}$$

and if each term in Eq (16) is multiplied by $\Delta x\ \Delta y$

$$R_2 \approx \frac{\Delta x_{23}}{\Delta y}\ ;\ R_1 \approx \frac{\Delta x_{12}}{\Delta y}\ ;$$

$$R_4 \approx \frac{\Delta y_{32}}{\Delta x}\ ;\ R_3 \approx \frac{\Delta y_{21}}{\Delta x}$$

If alternating currents were used, the construction of inductance or capacitance grids would be handled in a similar manner.

By extending this method, networks can be constructed for more complex equations such as that for transient heat flow

$$\nabla^2 T = K \frac{\partial T}{\partial t} + f(t) \qquad (18)$$

Here T is temperature, K is thermal conductivity, and $f(t)$ is an arbitrary heat function applied to the system. For the three-dimensional case, the network is shown in Fig. 4, with the left side of Eq (18) represented by the three-dimensional resistance network. The current proportional to $\partial T/\partial t$ is obtained by the capacitor to ground because $i_c = C\ \partial E/\partial t$, while the heat source, $f(t)$, is represented by the externally-supplied current, $i \approx f(t)$, at the junction. The required boundary conditions can be handled by suitable potentials.

The values of the resistors are determined in the same way as for Laplace's equation:

$$R_x = \frac{\Delta x}{\Delta y\, \Delta z}\ ,\ R_y = \frac{\Delta y}{\Delta x\, \Delta z}\ ,$$

$$R_z = \frac{\Delta z}{\Delta x\, \Delta y}\ .$$

The value of $C = K\ (\Delta x\ \Delta y\ \Delta z)$.

In many problems it is better to work in cylindrical or spherical coordinates. From a study of the manner in which the values of R_x, R_y, R_z and C were obtained and a consideration of the geometry of the systems, it is seen that in cylindrical coordinates:

$$R_r = \frac{\Delta r}{r\, \Delta \theta\, \Delta z}\ ;\ R_\theta = \frac{r\, \Delta \theta}{\Delta r\, \Delta z}\ ;$$

$$R_z = \frac{\triangle z}{r \triangle \theta \triangle r}\ ; C = (r \triangle \theta \triangle r \triangle z)\ K$$

and in spherical coordinates:

$$R_r = \frac{\triangle r}{r^2 \sin \phi \triangle \theta \triangle \phi}\ ;$$

$$R_\theta = \frac{r \sin \phi \triangle \theta}{r \triangle r \triangle \phi}\ ;$$

$$R^\phi = \frac{r}{r \sin \phi \triangle r \triangle \theta}\ ;$$

$$C = (r^2 \sin \phi \triangle r \triangle \theta \triangle \phi)\ K$$

In many problems of this type there is a certain degree of symmetry which can be advantageously used to reduce the number of components required in the network. For example, in a cylindrical problem with axial symmetry, it is necessary to use only a two-dimensional network in the z and r coordinates.

Operational Analogs

It is not always convenient to use the direct electric analog because of the difficulty of obtaining sufficiently high quality inductances and capacitances. In such cases the operational analog is often used.

In most of the analogous physical systems considered so far, there has been a one-to-one correspondence between the individual elements of one system and analogous elements in the other system. A distinct *type* of physical element is required in the analogous system for each distinct *type* of element in the original system. For example, in the electric analog of a mechanical system with voltage analogous to force, inductance is analogous to mass, resistance to viscous friction, and elastance (inverse capacitance) to stiffness. Such systems might be called *physical* analogs as opposed to *operational* analogs which will be discussed below.

Although these analogs have proven very useful in the analysis of many physical problems, they do have certain inherent limitations. It may not be possible, for example, to find a physically realizable element in one system that is analogous to a particular element in the other system. This is a very basic limitation. Mutual inductance and mutual mass, for example, are analogous elements in the voltage-force analog of simple electrical and mechanical systems. In some of the more complex mechanical systems, however, electrical transformers analogous to the mutual masses of the system are not physically realizable[4]. In most of these cases, an analogous electrical system can be found by a change in the dependent variable. A current-force analog of the system may be possible in which mutual capacitances are analogous to the mutual masses. Of course, the situation may also arise in which the current-force analog of a mechanical system is not physically realizable. Such situations tend to increase the complexity of establishing analogs and to reduce the over-all usefulness of the method.

It is a recognized fact that ideal elements in any physical system simply do not exist. Every spring has distributed mass, internal damping, hysteresis, and other properties, as well as its primary property of stiffness. Every mass has elastic properties, every inductance has resistance, and so on. Although the primary property of an element in one physical system may be ideally analogous to the primary property of an element in another system, secondary effects in the two supposedly analogous elements may depart from the ideal in radically different ways. This produces a consequent multiplication of the errors created by this non-ideal performance.

The most serious limitation of true analog systems is the difficulty encountered in constructing some types of elements so that they can be readily adjusted over a wide range of values. Adjustable elements of some types are relatively expensive, and the range of values over which they can be adjusted without introducing serious non-ideal characteristics may be quite limited. As a consequence, it may not be practical to analog a system over a wide range of variation of all the original elements. This leads to added expense and great inconvenience in the use of the analog. In electric analogs of mechanical systems, for example, variable capacitors and, in particular, high-quality continuously variable inductors are extremely difficult and expensive to construct. In addition, in-

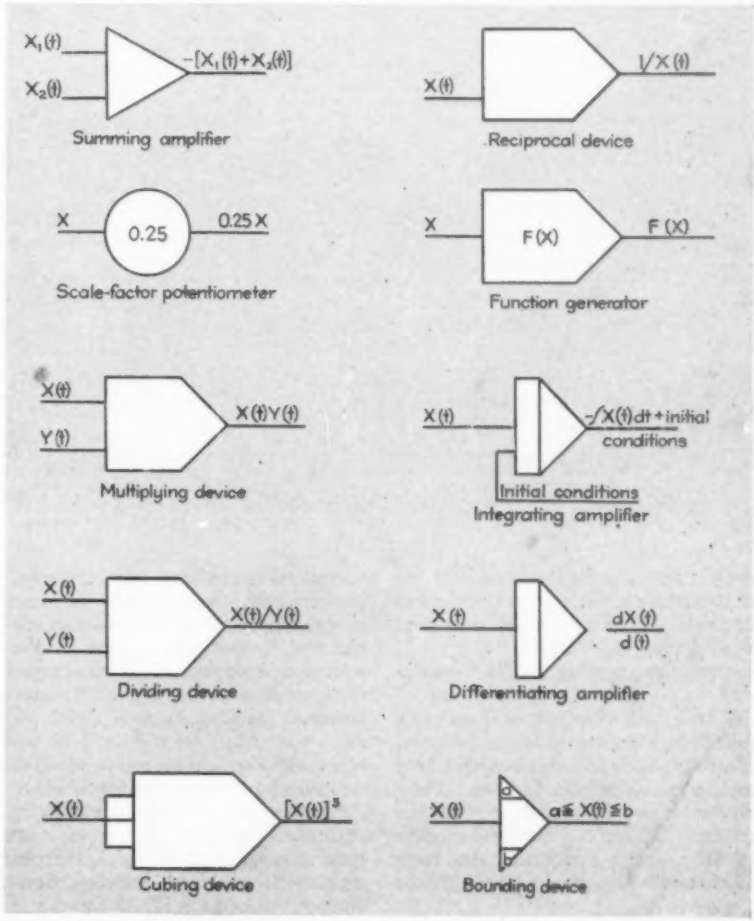
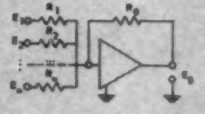
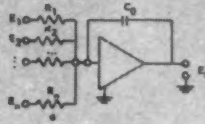
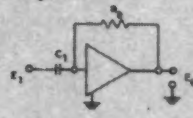
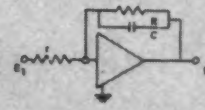
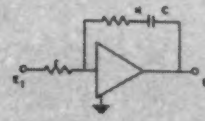
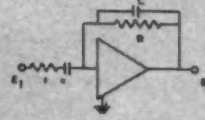
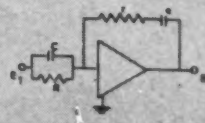


Fig. 5—Suggested symbols for various operational elements used in combination to produce commercially-available computers, such as differential analyzers.

Table III—Operational Amplifiers

Equation	Operation	Circuit	Output Function
$E_0 = -\frac{R_0}{R_1} E_0$	1. Scale and/or 2. Sign change		$E_0 = -\frac{R_0}{R_1} E_0$
$E_0 = -R_0\left[\frac{E_1}{R_1}+\frac{E_2}{R_2}+\ldots\frac{E_n}{R_n}\right]$	1. Summing 2. Scale change on each input variable 3. Sign change on all input variables		$E_0 = -\left[\frac{R_0}{R_1}E_1+\frac{R_0}{R_2}E_2\ldots+\frac{R_0}{R_n}E_n\right]$
$E_0 = -\frac{1}{\omega C_0}\left[\frac{\int E_1 dt}{R_1}+\frac{\int E_2 dt}{R_2}+\ldots\frac{\int E_n dt}{R_n}\right]$	Integration		$E_0 = -\frac{1}{C_0}\left[\frac{E_1}{pR_1}+\ldots\frac{E_n}{pR_n}\right]$
$E_0 = \omega R_0 C_1 \frac{dE_1}{dt}$	Differentiation		$E_0 = pE_1R_0C$
$\frac{dE_0}{dt} + K_1 E_0 = E_1$	Solution of first order linear differential equation		$E_0 = E_1\left[\frac{R}{r}\frac{1}{RCp+1}\right]$
$K_1E_1 + K_2\int E_1 dt = E_0$	Ditto		$E_0 = E_1\left[\frac{RCp+1}{rCp}\right]$
$E_1 + K_1\frac{dE_0}{dt} + (K_2+K_3)E_0 + K_3\int E_0 dt$	Solution of second order linear differential equation		$E_0 = E_1\left[\frac{Rcp}{(RCp+1)(rcp+1)}\right]$
$K_1\frac{dE_1}{dt} + (K_2+K_3)E_1 + K_3\int E_1 dt = E_0$	Ditto		$E_0 = E_1\left[\frac{(RCp+1)(rcp+1)}{Rcp}\right]$

ductors are notoriously non-ideal. As a consequence, the use of inductors in analogs is to be avoided whenever possible.

Operationally, analogous systems overcome most of the limitations of the so-called physical analogs. An operational analog is an assembly of elements, each of which performs a certain mathematical operation. These elements are assembled so that the equations describing the performance of the assembly are of the same form as those of the system for which the analog is desired.

The elements or building blocks for operational systems may be either actual physical elements with near-ideal performance characteristics or relatively complex devices developed specifically to perform certain mathematical operations. Electronic devices with nearly ideal operational characteristics are particularly well developed and these units have been widely used to analog physical systems whose performance can be described by ordinary differential equations. Commercially-available assemblies of such units are generally referred to as "electronic differential analyzers" or "electronic analog computers". Fig. 5 shows suggested symbols for the various operational elements of these assemblies.

The performance characteristics of a very large number of physical systems can be described by ordinary differential equations. In practice, the performance of a great many systems can be defined with sufficient accuracy by an ordinary linear differential equation with constant coefficients. The familiar form of such an equation

$$a_0\frac{d^n x}{dt^n} + a_1\frac{d^{n-1}x}{dt^{n-1}} + \ldots\ldots\ldots$$

$$a_{n-1}\frac{dx}{dt} + a_n x = f(t) \qquad (19)$$

represents only a few basic types of mathematical operations. These are

differentiation, multiplication (or division) by a constant, and summation (or subtraction). An operational analog for an equation of this type can be formed from an assembly of devices that perform only these three operations. By rearranging the equation, a similar analog can be formed using elements or devices that perform the operation of integration in place of differentiation.

Electronic operational elements with very nearly ideal characteristics have been developed by the use of feedback amplifiers in combination with static components. Fig. 6 is a schematic diagram of the general operational amplifier, and the relationship between the output and input voltages is given approximately by

$$E_O = -Z_O\left[\frac{E_1}{Z_1} + \frac{E_2}{Z_2} + \cdots \frac{E_n}{Z_n}\right] \quad (20)$$

where z_n is operational impedance.

The degree of approximation in this relationship is determined primarily by the gain of the amplifier, A, and by the input-grid current. For the solution of most engineering problems on a real-time scale, an amplifier gain of 50,000 or more, and an input-grid current of the order of 10^{-9} amp or less are acceptable values. Since negative feedback is necessary for stability, the amplifiers usually have an odd number of stages, and the input-output function involves a change in sign. Amplifier circuits have been developed which do not impose this limitation, but they are not widely used.

A great variety of operational elements can be derived from Eq (20). For the solution of ordinary differential equations, however, the only basic operations are summing, scale and sign changing, and either integrating or differentiating with respect to time. These are given by the first four circuits shown in Table III. Actually, the sign-changing amplifier is a simplification of the summer so that there are only three basic operations, summing, integrating and differentiating.

Fundamentally, the gain characteristic of any differentiator is an increasing function with respect to frequency. Consequently, differentiators amplify noise and tend to be unstable, thereby discouraging their use with an analog operating on a real-time scale. Successful differentiators have been built, however, for high-speed repetitive computers.

The precision linear potentiometer is another element that is useful for varying the scale factors in the analog. These basic elements—summers, integrators and potentiometers—are the

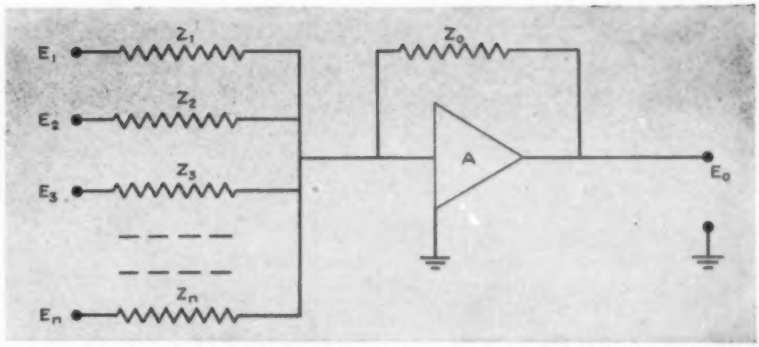


Fig. 6—Operational elements with near-ideal characteristics are generally combination of feedback amplifiers and static components of one kind or another.

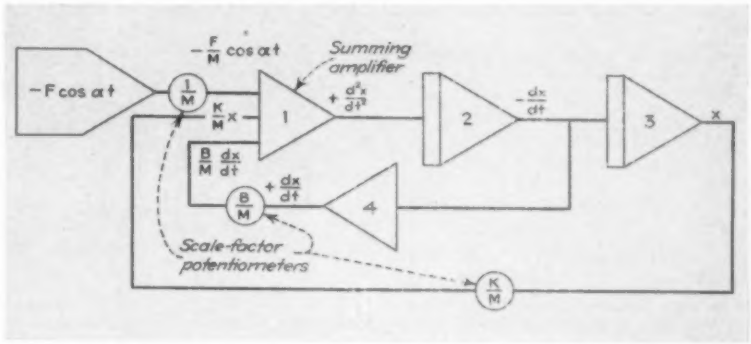


Fig. 7—Block diagram for operational integrating analog of mechanical system shown in Fig. 1(a). Inputs to summing amplifier #1 are modified by the potentiometers.

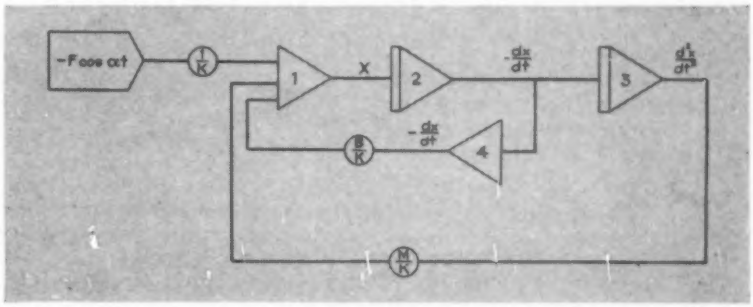


Fig. 8—Mechanical system of Fig. 1(a) as represented in form of an operational differentiating analog. Limitations of differentiators discourage use of this type.

essential building blocks of a computer for the solution of ordinary linear differential equations with constant coefficients. An assembly of these basic elements, together with associated power supplies, auxiliary elements and hardware, constitutes an electronic differential analyzer.

The method of interconnecting these elements to form an analog of a physical system can be illustrated by setting up the analog of the mechanical system of Fig. 1(a). The differential equation for this system is

$$\frac{d^2x}{dt^2} = \frac{1}{M}\left(F\cos\alpha t - B\frac{dx}{dt} - Kx\right). \quad (21)$$

If it is assumed that d^2x/dt^2 is generated by an operational element, then $-dx/dt$ can be generated by operating on d^2x/dt^2 with an integrating amplifier. Similarly, x can be generated by a second integrating amplifier. Since $F\cos\alpha t$ is the known forcing function, d^2x/dt^2 can be generated by a summing amplifier with inputs $F\cos\alpha t$, dx/dt and x, each modified by a suitable scale factor. These factors are provided by three adjustable linear potentiometers, and constant multipliers are provided by operational amplifiers. The connection block diagram of this operational analog is given in Fig. 7, where amplifier #4 is

(a) Problem Connection Tabulation

Eq(23): $L\frac{di}{dt} + Ri + U\frac{dx}{dt} = v_0(t)$

Amplifier	Variable	Operation	Type of Element
1	$\frac{di}{dt}$	$\frac{1}{L}\left[Ri + U\frac{dx}{dt} - V_0 t\right]$	Sum
2	$-i$	$\int \frac{di}{dt}\,dt$	Integrate
3	$+i$	$-i$	Sign Change

Eq(24): $M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx - Ui = 0$

Amplifier	Variable	Operation	Type of Element
4	$\frac{d^2x}{dt^2}$	$\frac{1}{M}\left[B\frac{dx}{dt} + Kx - Ui\right]$	Sum
5	$\frac{-dx}{dt}$	$\int \frac{dx^2}{dt^2}\,dt$	Integrate
6	$\frac{dx}{dt}$	$\frac{-dx}{dt}$	Sign Change
7	x	$-\int \frac{dx}{dt}$	Integrate

(b) Block Diagram

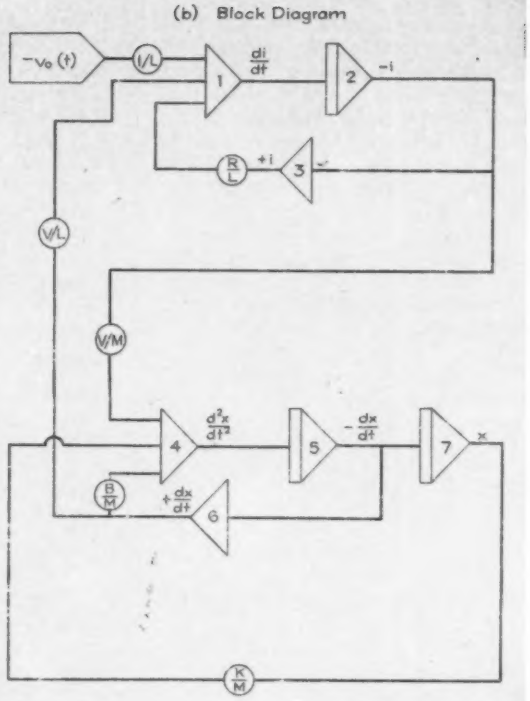


Fig. 9—Variables in simultaneous equations Eqs (23) and (24) are generated by separate operational elements as shown in connection tabulation (a) and block diagram (b). The more complex systems can also be analoged using similar systematic methods.

used only to change the sign of $-dx/dt$.

An analog using differentiators in place of the integrators can be formed in a similar manner by solving Eq (21) for x

$$x = \frac{1}{K}\left(F\cos\alpha t - B\frac{dx}{dt} - M\frac{d^2x}{dt^2}\right) \quad (22)$$

The connection block diagram for this analog is given in Fig. 8. However, this type analog is not normally used because of the above-mentioned limitations of differentiators.

It is usually more convenient to set up the analog so that each adjustable parameter in the original equation corresponds to a separate scale-factor potentiometer in the analog. This can be done simply in Fig. 7 by inserting a potentiometer corresponding to $1/M$ between amplifiers #1 and #2. The other potentiometers would then correspond to F, K and B, respectively.

A systematic method for setting up the connection block diagram can be demonstrated by means of an example. Assume that it is desired to analog the following set of simultaneous equations:

$$L\frac{di}{dt} + Ri + U\frac{dx}{dt} = v_0(t) \quad (23)$$

$$M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx - Ui = 0 \quad (24)$$

Each of the variables in these equations will be generated by a separate operational element in the analog. These elements are conveniently tabulated in Fig. 9(a) and the block diagram for a computer to solve these simultaneous equations is shown in Fig. 9(b). Operational analogs of more complex systems can be easily established by using similar systematic methods. The number of operational elements available determines the order of complexity of the problem which can be successfully analoged.

The amazing versatility of operational analogs offers many advantages in the solution of every-day dynamics problems. Since the only basic elements are amplifiers, capacitors, fixed resistors and potentiometers, suitable connection arrangements are set up so that any amplifier can be conveniently connected to perform any of the functions shown in Table III. Furthermore, the operational amplifiers can be easily interconnected to form the operational analog of a very wide variety of dynamic systems. Since the elements used are of standardized types, the size of the computer can be selected to correspond with the complexity of the problem to be solved. Special elements are easily added to accommodate more complex problems.

A relatively small number of operational elements will often accommodate a wide variety of common problems that are tedious to solve by manual methods. Although the solutions to many of these problems may be relatively straightforward, the complete evaluation of the system over a wide range of system parameters may require considerable computational work.

Consider, for example, the mechanical system of Fig. 1(a), but assume that the point of attachment of the spring, K, to the vertical reference is actually subjected to a horizontal displacement caused by vibration, $Y_o \cos \beta t$, with respect to the reference. Also assume that the force $F(t)$ is replaced by a suddenly applied acceleration a. Suppose that it is desired to select suitable values of M, B, and K such that the peak displacement of the mass M will never exceed a maximum value x_2, and such that it will reach a minimum value of x_1 within a given time interval T_1 over a range of values for a. It is also desired to realize the

maximum possible isolation of the mass from the vibration $Y_0 \cos \beta t$. This is a somewhat simplified representation of an actual design problem. The optimum values of M, B and K, and the over-all performance of the system are not immediately apparent by inspection and, although it is a relatively simple system, its evaluation over a wide range of values of M, B and K would be tedious and time-consuming.

The differential equation for this system is

$$M \frac{d^2x}{dt^2} + B \frac{dx}{dt} + K(x - Y_O \cos \beta t) = a[u(t)] \qquad (25)$$

where $u(t)$ is a step function. The connection block diagram of an operational analog for this system appears in Fig. 10. This computer illustrates the usefulness of even a very few operational elements.

Perhaps the greatest advantage of such simple computers is the ease with which certain types of common nonlinearities can be incorporated. Very simple devices will accommodate such nonlinearities as limit stops, coulomb friction, hysteresis and backlash. These factors are present in every dynamic system to some extent and are extremely difficult to handle by normal analytical methods.

As an example, suppose that the system described by Eq (25) is further modified by a coulomb-friction factor to give

$$M \frac{d^2x}{dt^2} + B \frac{dx}{dt} + G \frac{dx}{dt} + K(x - Y_O \cos \beta t) = a[u(t)] \qquad (26)$$

where

$$G = \begin{cases} G_1 \text{ for } \dfrac{dx}{dt} > 0 \\ -G_1 \text{ for } \dfrac{dx}{dt} < 0 \end{cases}$$

In this equation, the function G is easily simulated by a differential relay and a high-gain saturating amplifier together with a suitable voltage source. The connection diagram of the analog for this system is shown in Fig. 11. Amplifier #5 can be a single high-gain stage used to reduce the dead zone of the relay for small values of dx/dt. It should saturate for large values of dx/dt to avoid damage to the relay. Simple diode circuits can also be used in place of the relay. The effects of coulomb friction on the performance of this system can be explored with this simple computer.

The simple mechanical system of Fig. 1(a) may be further complicated by hysteresis in the spring, limit stops and similar factors. These may be important in the physical system, but are usually ignored in the analysis since their investigation by manual methods would be economically impossible. The use of small operational analogs, however, permits these factors to be economically and conveniently investigated by simple, straightforward techniques.

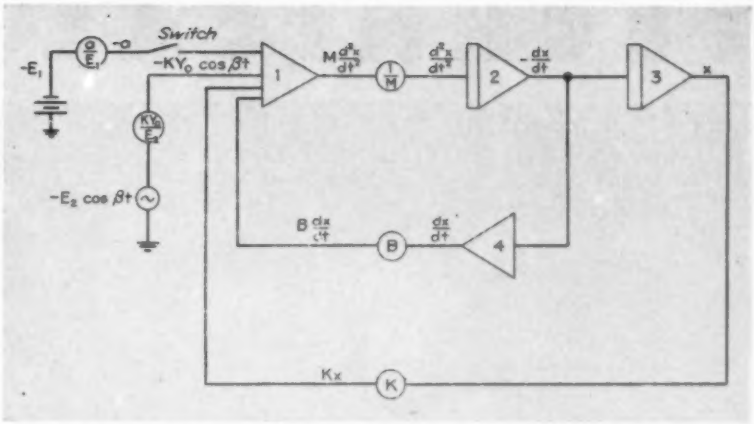


Fig. 10—Simple mechanical system of Fig. 1(a) modified by subjecting right end of spring to horizontal vibratory displacement. Optimum values of M, B and K as well as performance of system, are easily evaluated with analog shown.

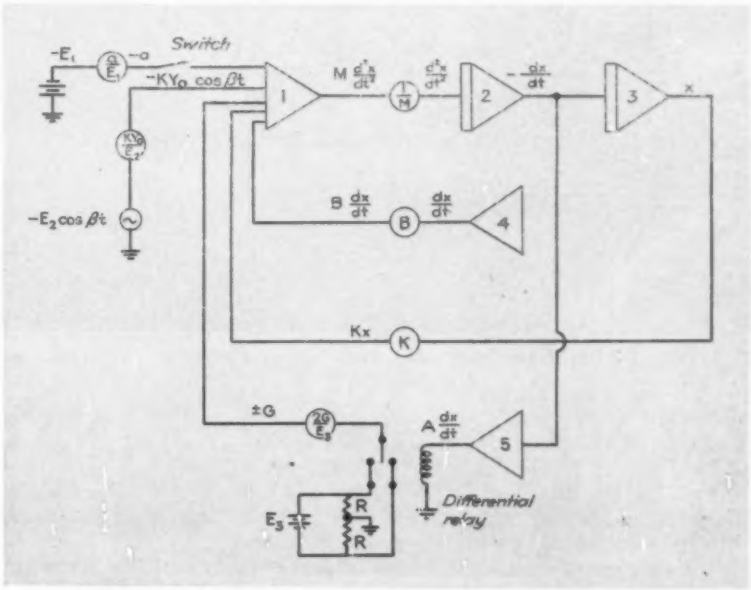


Fig. 11—Simulation of common physical nonlinearities such as coulomb friction is illustrated by addition of a differential relay to the analog circuit. Other analogous factors (M, B and K) in diagram are similar to those in Fig. 1(a).

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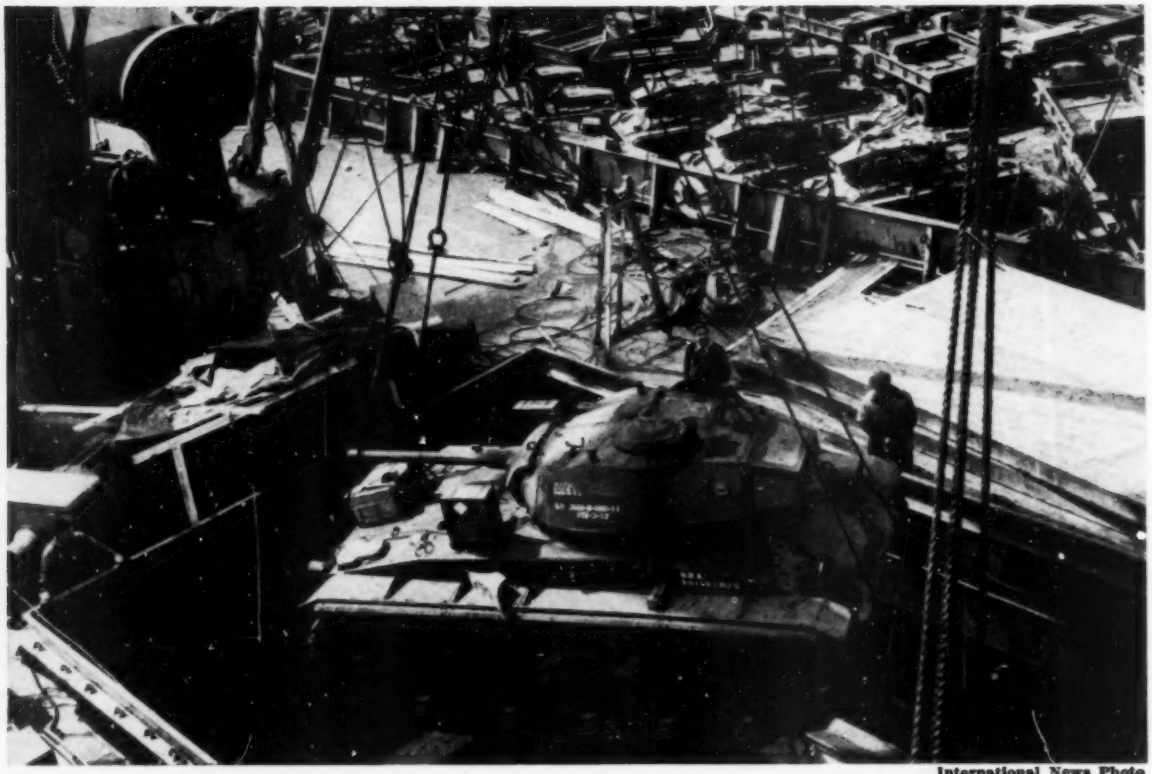
TECHNICAL NEWS



International News Photo

DELIVERY OF free United States tanks, trucks and other weapons to European Countries helps train soldiers but . . .

Lack of Standardization Stalls NATO Rearmament

PARIS—As the 14 North Atlantic Treaty Organization nations went through recent field maneuvers in Europe, observers easily recognized one major obstacle to Western rearmament. Standardization of equipment for NATO forces is moving ahead at a snail's pace. As one official put it "weapon standardization is like European Unity: it's coming but it's a long way off."

▶ **Politics first.** When standardization comes, design is likely to be relegated to a secondary role. Important political and economic questions will weigh more heavily than pure design considerations. The problem: each nation's pride in its own industry and its familiarity with its own national weapons slow up acceptance of generally agreed standard weapons. Too, the major nations like Great Britain, United States, and France are determined to maintain their own aviation, armament, and military supplies industries in healthy and vigorous condition. This calls for the purchase of products these industries design and manufacture.

And from the economic viewpoint, the time and expense involved in a change-over from one type weapon to another is almost prohibitive at the present time, even if only two or three of the 14 countries make the change.

▶ **U. S. Aid Helps.** Meanwhile in London, the Military Standardization Agency of NATO has started wrestling with the problem. So far they have limited their discussions to solving procedural problems.

The biggest push towards standardization stems from U. S. aid to NATO nations. Hard-pressed to finance their own rearmament, they are eager to accept free tanks, guns, and airplanes of American design. In addition, American "offshore" purchases of European produced weapons tend to concentrate production on specific weapons in a single class.

▶ **Standard weapons vs. standardization.** Weapons the U. S. buys from NATO producers are called standard weapons. But this is not standardization. A standard weapon is one that may, under special circumstances, be made available to any NATO force; it is not a weapon intended as standard equipment for all NATO forces.

Officials explain it this way. The United States is about to order $86,000,000 worth of Dassault Mysteres, a French interceptor plane. All of these planes are intended for the French Air Force. However, in an emergency, if a squadron of U. S. Air Force men were available and needed but had no aircraft, they could be equipped with French Mysteres should those planes be available.

▶ **Offshore in jeopardy.** But even the offshore purchasing program has run into heavy-going because of lack of standards. William L. Batt, retiring U. S. minister for economic affairs to the United Kingdom, told the Ameri-

can Standards Association that a lack of uniform standards in drafting procedures of Great Britain, Canada and the U. S. was the most serious technical roadblock impeding NATO's rearmament program.

The U. S. is procuring arms of American design in Europe to the tune of $729,000,000. But so much production time is being wasted redrawing prints to fit shop practices of individual countries that the whole program is in jeopardy. Batt claims that standardization of drawings is the most important single step NATO could take to make better use of their combined resources.

▶ **Follow Russian lead.** In urging industrial leaders of the three countries to take immediate steps to standardize practices, Batt warned that the Soviet Union has already recognized this same problem in their satellite countries. The Reds are pushing all seven iron-curtain countries to standardize their production and weapons with the Soviet. As a result, recent Czechoslovakian standards carry the same number as the Russian standards on the same subject, have titles in both Russian and Czech, and carry notations on their differences.

Standardization is not work for governments alone according to Batt. "To be truly effective, standardization must be based on sound engineering practices. The job can be done properly only by joint effort of individual enterprises and governments in the countries concerned."

While NATO officials recognize the problem, they can't boast of too many solutions. To date there is only one NATO weapons standardization agreement. That applies to ammunition components, principally gun powder. However, NATO spokesmen claim that they have made substantial progress towards standardization of some supplies like jet engine fuel and some aviation servicing equipment.

Stretching the Supply of Engineers

HOW TO MAKE BETTER USE OF currently employed engineers is the subject of a report recently prepared by the National Society of Professional Engineers, Washington, D. C. According to NSPE, engineer efficiency in industry is being sapped by inadequate working facilities, too much detail work, and improper training. In the report, the society pools the experience of some 500 companies, employing over 100,000 engineers.

NSPE points out that nobody is getting the number of engineers they would like to have. With college enrollments sliding and high school population decreasing, the only solution to the engineer shortage appears to be more efficient utilization of those already employed.

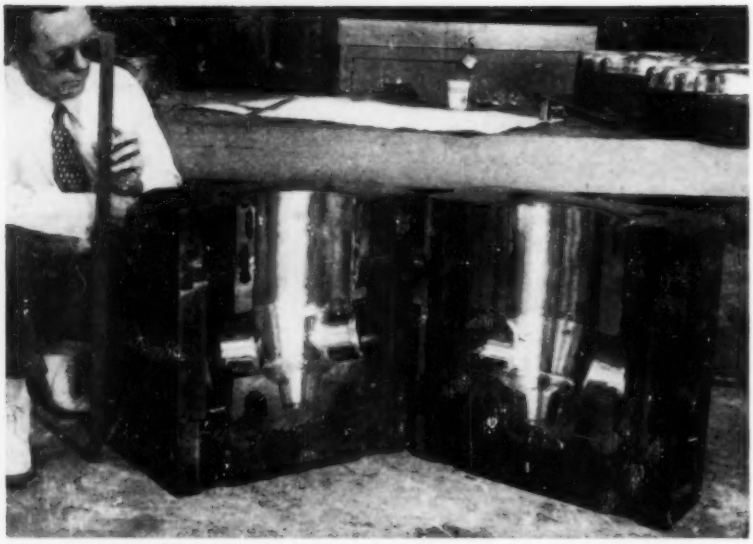
Here are some typical suggestions offered by the report:

- Improve working conditions with respect to noise level, environment, equipment, and lighting. Minor changes such as more telephones, and the elimination of traffic through the office can boost the engineering department's productivity.
- Use neighboring facilities for training and consultation. Some sources of outside help: universities, engineering consulting firms, drafting contract firms, retired engineers, research organizations, and noncitizen engineers (for non-classified work).
- Let women clerks help with engineering details to the limit of their capabilities. Work technical aids procured from institutes with 18- to 24-month training courses into the engineering program where possible. Try technical-minded high school graduates and college graduates with arts degree on engineering detail work. All of these people can handle items such as data collection and collation, expediting, material orders, market research, drawing changes, preparation of charts and graphs, and general legwork.
- Increase the use of standard practices to eliminate detail work. Use punch cards and similar aids to make engineering data available easily.
- Compromise with perfection when the next best thing will save time and money.
- Solicit and encourage ideas from all engineering personnel levels through the medium of the conference. Help educate younger engineers by permitting them to participate in conferences affecting basic technical decisions.
- Boost engineer educational levels by offering paid, time-off periods for attendance at training courses and symposiums.

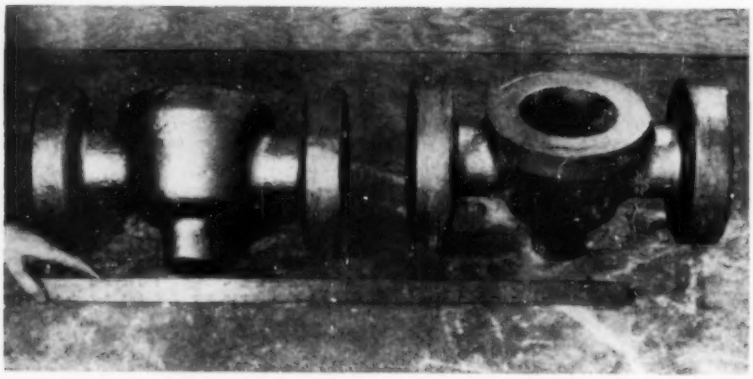
In reviewing the engineering situation, NSPE found that charges of engineer hoarding were generally not justified. Engineers in the companies surveyed reported that they spent about 85 percent of their time in technical pursuits. However, a few firms still use engineers in industrial relations and customer relations.

The society also reports that engineer training is one of the weakest spots in industry's program. Most companies are putting engineers to work as soon as they clear personnel.

SYLVANIA ELECTRIC PRODUCTS introduced this unique packaging idea when they unveiled their new Bantam flash bulb. Carton is perforated so that user or retailer can break it into thirds, each containing four bulbs, for easier handling. Sylvania made package 25 percent smaller than conventional flash bulb carton by using chipboard instead of corrugated board. New bulb, developed to service improved films and lenses which require less light than that supplied by press-type flash bulbs, provides 7,000 lumens, compared to 20,000 for the smallest flash bulb currently available.



SPLIT DIES permit producing in a single operation from a round billet . . .



THIS VALVE BODY capable of withstanding extreme hydrostatic pressures.

Processes: Press-Forging Heavy Steel Parts With Split Dies

HOUSTON—When sand holes and other defects in steel castings caused failure of parts under high hydrostatic pressure tests, Cameron Iron Works, Inc., big manufacturer of pressure control equipment used in drilling oil and gas wells, perfected a press-forging technique that uses a split die. Turning out a metallurgically superior product, the new method significantly reduces manufacturing costs.

While looking for a way out of their specific problem, Cameron engineers found that press-forging produced satisfactory parts from non-ferrous metals and alloys as well as small and simple steel parts. Key to the technique was a three ram press capable of vertical or horizontal piercing and squeezing. But there was no equipment available to handle something like an intricate-shaped 2,000 lb well head.

▶ **Three Ram Press.** A. B. Farquhar Co. solved the equipment deficiency by building a press with a vertical ram that can exert a force of 5,000 tons, and two side or horizontal rams rated at 2,000 tons each.

In most forging operations, the side rams hold the split die together while the vertical ram displaces metal into the cavities of the die and pierces the ingot. However, the side rams can be used for pressing and piercing while the main ram holds the die.

▶ **Finished Product.** Metallurgical studies indicate that the forgings possess qualities of grain structure, homogeneity, and freedom from defects that cannot be duplicated by castings. Reason: in forgings, grain flow can be controlled to obtain the optimum pattern in the finished product. From a production standpoint, it is relatively easy to turn out good forgings with the proper equipment, but difficult to produce good castings. Too, ordinary pressure testing methods and inspection of castings can't be relied upon unless expensive techniques like 100 percent x-ray inspection are performed.

Primary saving in manufacturing costs stems from reduced labor content in the forging process. While cost of a press-forging increases with more intricate shapes that require expensive dies, reduced number of rejects more than makes up for the added expense. In addition, Cameron has found that the forgings are easier on cutting tools than castings with a considerable saving in items like thread chasers. For example, with sand castings, Cameron used 14 sets of thread chasers per month on large parts; with forgings they require only two sets per month.

▶ **Saves Alloy Materials.** Another advantage of press forgings is the fact that desired properties can be obtained with minimum amounts of critical alloys. In one case, a casting with high impact strength at low temperatures and high tensile strength required 3½ to 4 percent nickel; a forging with the same properties needs only 1.75 percent nickel.

Press-forgings produced in split dies need practically no draft. There is no flashing to be removed from the rough forging. Conventional forgings require a certain amount of draft which usually necessitates an additional machining operation. Split die forgings come from the die with no excess stock except that allowed on surfaces that require machining.

▶ **Versatile Method.** Cameron claims that this technique permits, for the first time, the production by forging of intricate shapes that have been previously limited to steel castings. The application of the technique to aircraft and ordnance components has resulted in such savings that the company with the U. S. Government is increasing their facilities with a new press whose main ram will be rated at 11,000 tons, and the side rams at 6,000 tons each.

Pneumatics Threaten Hydraulic Supremacy in Aircraft Design

HYDRAULICS, the workhorse in aircraft control systems, may give way to lighter more versatile pneumatic systems. Daniel Mapes, Vice President, Research and Engineering, Walter Kidde & Company, Inc. predicts that the switch will come in the next few years.

▶ **History.** Actually, pneumatics in aircraft control systems got their start during the last war. The British used 400-600 psi systems to a limited extent to operate brakes and landing gear on fighter planes. After the war, they continued to use such systems on military trainers. In the United States, development was even slower. U. S. designers limited pneumatics to such minor tasks as gun charging.

According to Mapes, aircraft designers avoided pneumatic systems in the past because there was no compressor that would meet the tough specifications of aviation duty, and the designers were unfamiliar with pneumatic controls. When Kidde developed their lightweight compressor (*Product Engineering*, April, 1952, p. 140) the aviation industry got interested. As a result, Kidde engineers designed a complete pneumatic system for Republic's F84G fighter.

Heart of this system is the new compressor that weighs only 14 lb, but can deliver in excess of four cu. ft. of free air per minute at a pressure of 3,000 psi. Such an output, singly or in series, is sufficient to power all controls, on present day planes, that are now hydraulically or electrically actuated.

▶ **More support.** In September, pneumatic systems for aircraft got another boost. The Air Transport Association's report on "Design Recommendations for Turbine Powered Aircraft" suggested that pneumatic systems be studied as the primary power source for control equipment instead of hydraulics.

In discussing both this report and Kidde's F84G design, Mapes cites these advantages of pneumatic systems:

- Simplicity. Pneumatic systems are generally simpler than electrical or hydraulic types.
- Weight. Such systems represent a considerable weight saving over the other types.
- Safety. Air controls would eliminate the fire hazard associated with hydraulic fluids and electricity, and the air is non-corrosive and non-toxic.
- Maintenance. Pneumatic systems would be easier to maintain since slight leaks do not affect performance to the same extent they do in a hydraulic system.
- Versatility. Air controls operate over a wider temperature range than other types; they are less vulnerable to damage; and they permit exceptionally high energy delivery rates necessary to operate large loads like bomb bay doors.

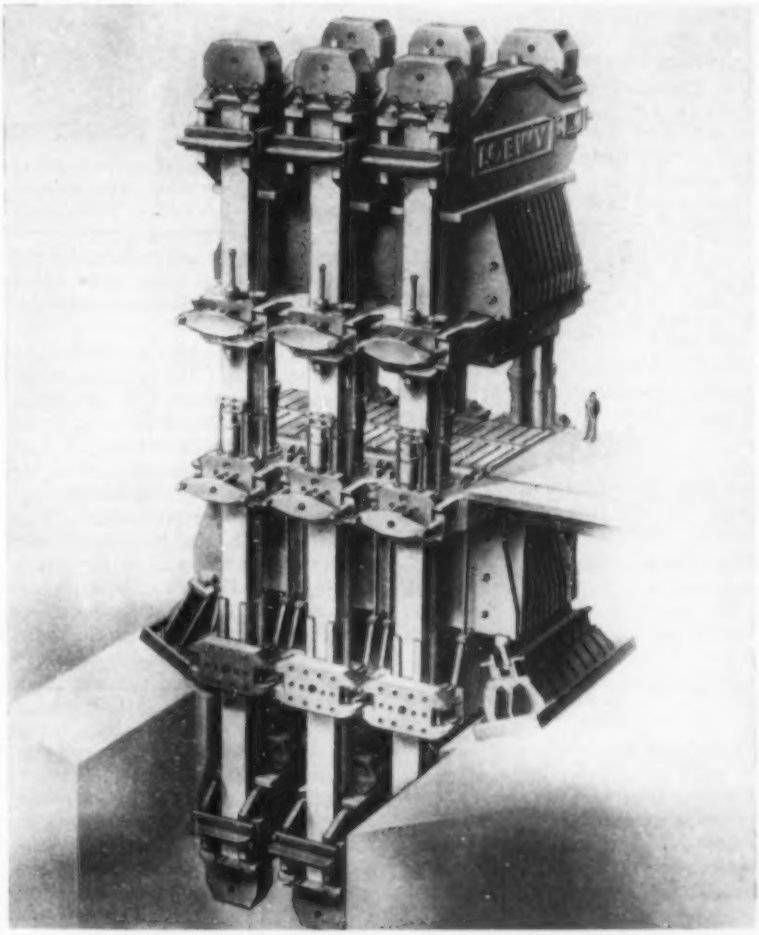
WSB Clarifies Engineer Definition

WASHINGTON—The Wage Stabilization Board has announced a broader definition of the "professional engineer" who is exempt from wage and salary controls.

Previously WSB permitted exemption only if the engineer held a professional engineering degree from an accredited college or university, or if he was licensed or registered to practice as a professional engineer (*Product Engineering*, August 1952, p. 190).

Now the board adds that an employee who performs the same services or fills the same job as other employees who hold an engineering degree or license qualifies as a professional engineer, even though he himself does not have a degree or license.

In general, WSB explains, an engineer who is employed in a professional capacity which makes him exempt from the Federal Wage-Hour Law is also exempt from wage and salary controls. This was one of the last rulings made before WSB's December collapse.



50,000 TON CLOSED DIE hydraulic press, part of the Air Force's heavy press program, will be installed at Wyman Gordon's North Grafton, Mass. plant to mass produce large forgings and extrusions from various metals. The new tool, hydraulically operated, stands 10 stories high and weighs 11,000 tons.

Danes Design Low Cost Auto

THE DOLLAR SHORTAGE IN DENMARK is the driving force behind the design of a new full-sized automobile that has a laminated polyester plastic body and floor. While it fits American dimensions on the interior, the six passenger DK-car retains European standards of driving economy, weight and exterior dimensions.

Main reason for the use of plastic is the reduced investment involved. Denmark has no automobile manufacturing industry now (they do produce motorcycles and bicycle engines). To start a plant, a Danish firm would have to invest close to $300,000 to buy presses, dies, and tools for the fabrication of steel bodies. The plastic bodies will require an investment of only about $25,000.

▶ **Other advantages.** Danish engineers claim other advantages for the new body material. Because of its lightness, the plastic permits making a larger capacity automobile without requiring high fuel consumption, or more powerful engines. Mechanically, the plastic retains good strength and elasticity and cannot be dented. Corrosion and rustproof, the surface attains a high lustre without treatment and keeps it. The Danes also point out that unskilled labor can produce the plastic bodies without extensive training.

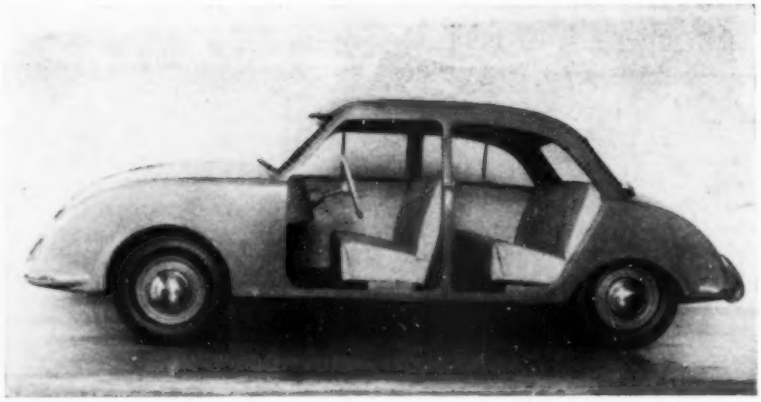
On the debit side, plastics are more expensive than steel. Too, production of plastic bodies is economically feasible for limited quantities, about 10,- to 15,000 units. This isn't a serious limitation in Denmark where the demand for new cars is currently estimated at about 30,000.

▶ **Car Features.** The first all-Danish designed automobile uses a three cylinder, two cycle engine with a compression ratio of 6.8:1 to turn at a maximum of 40 bhp at 4,500 rpm. The transmission consists of a single dry plate clutch and a four speed gear box with the gearshift lever fitted through the instrument panel.

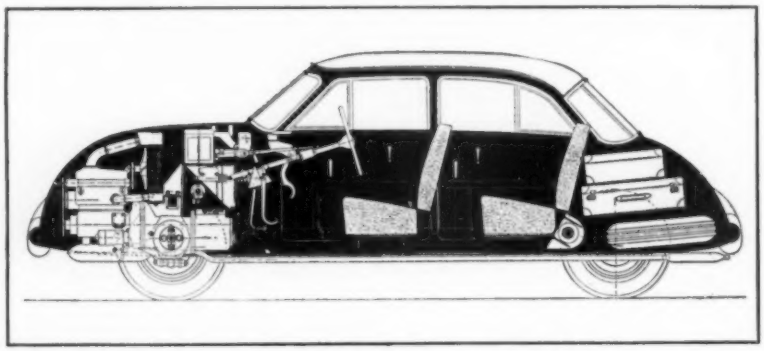
An enclosed transverse leaf spring with hydraulic shock absorbers and wishbone links for both wheels make up the front suspension. In the rear, leaf springs of the torsional type work in grease and are totally enclosed. Also there are double acting telescopic shock absorbers to help cushion road shocks. Hydraulic four-wheel brakes and a mechanical hand brake operating on the rear wheels complete the chassis.

With a light metal frame, about 190 lb, the entire plastic body will weigh only 365 lb. The overall weight of the car unloaded is 1,550 lb. When they get into production, the Danes estimate the DK-Car will cost $1,320.

Denmark's new auto industry will get its start in a plant built by the Germans during the World War II occupation at Thisted, in Jutland.



FIRST ALL-DANISH-DESIGNED AUTOMOBILE, The DK-Car, uses plastic body and floor and light metal frame. It is one of the few six passenger European cars.



UNUSUAL GEAR SHIFT ARRANGEMENT is fitted through the instrument panel. Car is a front wheel drive; engine and transmission fit into engine compartment leaving remainder of car for passengers and luggage.

Dangerous New Products Cost Manufacturers Million

WHEN A COMPANY UNVEILS A NEW PRODUCT it usually visualizes new business, bigger profits, and an increased share of the market. It doesn't think about or expect a flock of lawsuits and claims. Yet each year millions of dollars are lost because companies fail to consider hazards generated by new products.

At the December ASME meeting, the safety division considered this problem. Presented by John V. Grimaldi, Industrial Division Director, Association of Casualty and Surety Companies, one paper pointed out that product designers are falling down on their responsibility in many cases. Concentrating on engineering and sales features, men who develop new products forget to determine if a product might cause destruction of property, injure the public, or constitute a health hazard.

▶ **Tougher courts.** Recent court decisions are making it tougher on manufacturers. Traditionally, the policy of "buyer beware" has prevailed; now it is switched to "seller beware". The question is not whether the manufacturer is right or wrong

about the hazards of his product, he must be able to prove that his product is free from perils when any liability claims are made against him.

New judicial rulings have ruined one favorite criterion used by manufacturers. Previously a manufacturer was in the clear if he could prove that "almost everyone could use his product safely". In a recent court case, the judge ruled: the mere fact that only a small proportion of those who use a certain article would suffer injuries by reason of such use does not absolve the vender from liability under the implied warranty. Otherwise in every damage action it would be necessary to prove that the article sold would injure every user."

▶ **What to do.** Experts agree there are two means of protecting against financial loss:

- Product liability insurance that guarantees protection within the limits of the policy.
- Determine possible hazards before marketing, then control or eliminate them.

Actually, insurance people recommend that both approaches be used. They point out that an insurance policy never prevented an accident. Too, the losses often exceed the limits of the policy and the company must carry the excess alone.

Product liability policies usually cover accidents that occur off the premises of the insured, and after he has relinquished possession. Some manufacturers have destroyed their own plants and equipment while turning out new products that were not checked for hazards. Product liability insurance doesn't cover such losses.

▶ **Determining hazards.** Here's a quick check list of what the designer should do with every new product.

- Look for inherent hazards in the product that might effect his own plant structure or equipment. Typical examples: Does product create a fire hazard; check materials used in manufacture to gain accurate knowledge about flash points, ignition temperatures, corrosiveness, vapor pressures, and other physical properties.
- Check health hazards to production personnel. Look for toxicity or corrosiveness to skin tissue of the product or materials used in manufacture.
- Determine if public health will be impaired through use or exposure to the product.
- Consider possible hazards to property. Look for electrical, mechanical or chemical difficulties that might impair the product itself or surrounding objects.

Experts point out that the product should be tested under actual operating conditions whenever possible. Failure to do this can be costly. For instance, one of the leading automobile manufacturers is faced with heavy damage suits because they failed to properly test engine flywheels. The design permitted the formation of critical frequencies under certain operating conditions. Result: the flywheels exploded sending shrapnel into the passengers' compartment.

In addition, someone with legal training should check laws and regulations that apply to the product and then warn the designers what they can or cannot do. Laws vary from state to state, and usually they stress labeling, ingredients, guarantees, and instructions for use.

▶ **Labeling.** Finding potential hazards in a product doesn't end a company's responsibility. If the label doesn't clearly describe the hazards and precautions to be taken, the courts will hold the manufacturer liable. For example, a dry cleaning fluid had on its label "Caution, use in a well ventilated place, do not inhale fumes." However, it was marketed under a trade name that included the word "safety". When a housewife ignored the instructions and died, a court promptly awarded the husband $10,000. Judge's reasoning: the fluid was highly dangerous as proved by the tragic result, and the victim should have foreseen the danger by the warning on the label. But the word safety appeared so prominently all over the container that it made the warning appear unimportant. The company is guilty of improper labeling.

Proof that hazards in new products are a serious problem is demonstrated by the number of business failures they cause. Experts estimate that 25 percent of new enterprises fail each year because of faulty product design. Typical example: a company formed to make a new automobile engine antifreeze marketed their product without checking for hazards (specifically corrosion properties). For protection they took out a $25,000 product liability policy. Within three months damage claims exceeded the $25,000 policy limit, even though the average claim was under $100. Within 9 months the figure had soared to $100,000 and the company went bankrupt.

▶ **Why risk it?** Why do companies risk ruin this way? Insurance men offer several explanations. Small companies often don't have the money to make extensive tests, so they take a chance, hoping an insurance policy and luck will protect them. Or a new company will try to get its investment back too fast. Sometimes competitive situations force a company to market a product before they are really satisfied with it. And, there's always the urge for even a big company to be known as the "first" in a field or as a pioneer. So they market a product before it's been adequately tested.

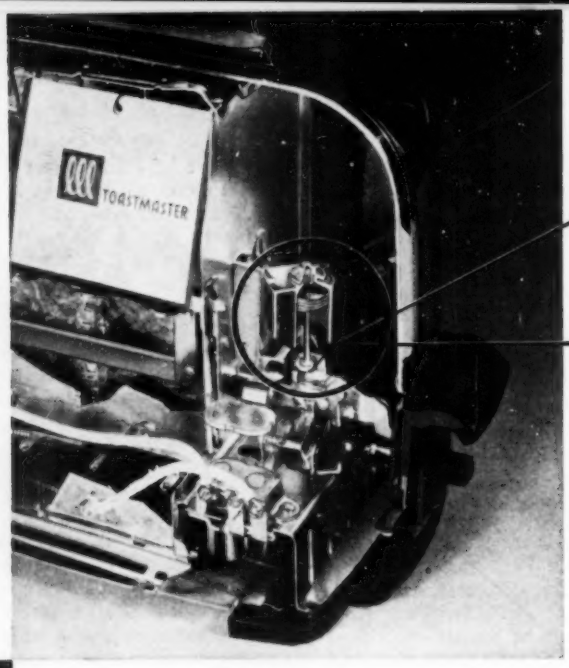
New materials often require as much as five or ten years before all their properties are known. Economic conditions may prevent the company from holding a product back that long.

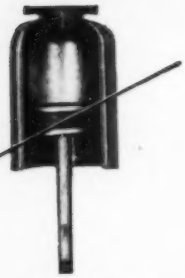
Another headache for producers of new products is improper use of their equipment. While the courts won't award damages in such cases, the company still is plagued with claims, costs of court litigation and loss of good will. The only answer here appears to be proper education of customers.

▶ NEOPRENE MESH, made by Research Products Corporation, Madison, Wisc., cushions delicate parts during manufacturing operations. Composed of a Neoprene jacket applied to an expanded fiber core, the mesh is about $\frac{3}{16}$ in. thick with $\frac{3}{8}$ in. diamond-shaped openings. Main advantage of the material over natural rubber is it's superior resistance to oil, gasoline, heat, and abrasion as well as to caustics and other chemicals.

▶ MODIFIED UREA FORMALDEHYDE resin increases the wet-strength of paper by providing quick and close combining of the resin and cellulose fibers. Casco-Resin PR-160, a cationic type material made by the Chemical Division of the Borden Company, can also be used with non-ionic or cationic wetting agents to increase the absorbency of paper. PR-160 has a minimum storage life of four months at 70F.

▶ GRATING SPECTROMETER designed at the University of California will permit the study of electro-magnetic radiation in the "no-man's land" of the far infra-red spectrum. Developed primarily to aid scientists study forces operating between molecules and atoms, the device consists of a metal grating on which are cut carefully shaped grooves that break up light into its various components, an oscillating salt plate to chop the infra-red light into pulses, and mirrors sensitive to light of specific wave lengths.





Restrictions on brass forced engineers in the Toastmaster Products Division of McGraw Electric Company to find substitute materials for a pneumatic damping device on the toast ejector mechanism. They had been using a cylinder, machined from solid ¾ inch brass rod, and a precision ground brass piston with a connecting rod on a swivel joint. The cylinder head was fitted with a spring and ball check valve. Tolerances on this complicated assembly had to be held within 2 mils to give satisfactory performance for at least 100,000 cycles at 350° F.

On pneumatic dampers

SILASTIC* simplifies design

...saves critical materials

Many substitute materials and designs were tried with disappointing results before one of our technical representatives dropped in with samples of Silastic. Using this heat-stable, rubbery silicone product, Toastmaster's research and development engineers perfected a very simple and durable damper. It consists of an inexpensive drawn steel cylinder, a 1-piece connecting rod, and a flat ring-shaped Silastic piston mounted loosely between two metal cup washers with a simple air leak past the shoulder of the piston.

Tolerances on the new damper are large; the cylinder can be out of round; 86 pounds of mild steel displace 199 pounds of brass per 1000 toasters. *And the new device works better than the more expensive brass assembly.* Such performance proves the usefulness of Silastic as a new engineering material. It retains its rubbery properties and its good dielectric properties at temperatures ranging from below —70 to above 500° F. It is highly water repellent; shows excellent resistance to weathering and to a variety of hot oils and chemicals.

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Common Rubber Materials

TYPE *	NOTABLE PROPERTIES	LIMITING PROPERTIES	TYPICAL APPLICATIONS
NATURAL RUBBER			
Natural Rubber (R)	Good resilience; high tensile strength and elongation; wide hardness range; long flex-life.	Heat, oil, weather and ozone resistance.	Tires, tubes, motor mounts, general mechanical goods.
SYNTHETIC RUBBER			
Butadiene-Styrene Copolymers (Buna S) (GR-S) (R)	Abrasion and heat resistance, resilience, hardness range.	Oil, tear, weather and ozone resistance.	General substitute for natural rubber, tires, mechanical goods.
Butadiene-Acrylonitrile Copolymers (Buna N) (GR-A) (SB)	Abrasion, heat and aging resistance; resistance to mineral oil, gasoline, organic solvent, dilute acid and alkali.	Resilience, tear resistance, processing.	Hose, seals, diaphragms, oil resistant mechanical goods.
Chloro-butadiene Polymers (Neoprene) (GR-M) (SC)	Excellent weather and flame resistance; heat and aging resistance; flex-life; medium oil and chemical resistance.	Hardness range; cold resistance; processing.	Electrical insulation, hose, mechanical goods of moderate oil and weather resistance.
Isolbutylene Copolymers (Butyl) (GR-I) (R)	Good weather, ozone, acid and alkali resistance; excellent impermeability to gases.	Low tensile strength, resilience, abrasion resistance, inflammable.	Inner tubes, radiator and heater hose, ignition nipples.
Polysulfide (Thiokol) (GR-P) (SA)	Maximum oil and solvent resistance; weather and ozone resistance.	High compression set, low tensile strength and elongation, heat resistance.	Paint spray and gasoline hose, gaskets.
RUBBER-LIKE MATERIALS			
Polyvinyl Chloride	Oil and chemical resistance; dielectric strength; weather and ozone resistance.	Resilience, poor rigidity at elevated temperatures.	Ignition nipples, wire insulation, packaging materials.
Silicone (TA)	Maximum heat and cold resistance; water and oil resistance.	Low physical properties, resilience, cost, high compression set.	High temperature gaskets, coverings and mechanical goods.
RECLAIMED RUBBER			
Reclaimed Rubber (R)	Ease of processing and forming.	Tensile strength; abrasion, aging, weather and ozone resistance.	Toys, novelties, waterproof footwear, general mechanical goods of a non-critical nature.

* Government Reserve (GR) and SAE-ASTM designations are shown in parentheses.

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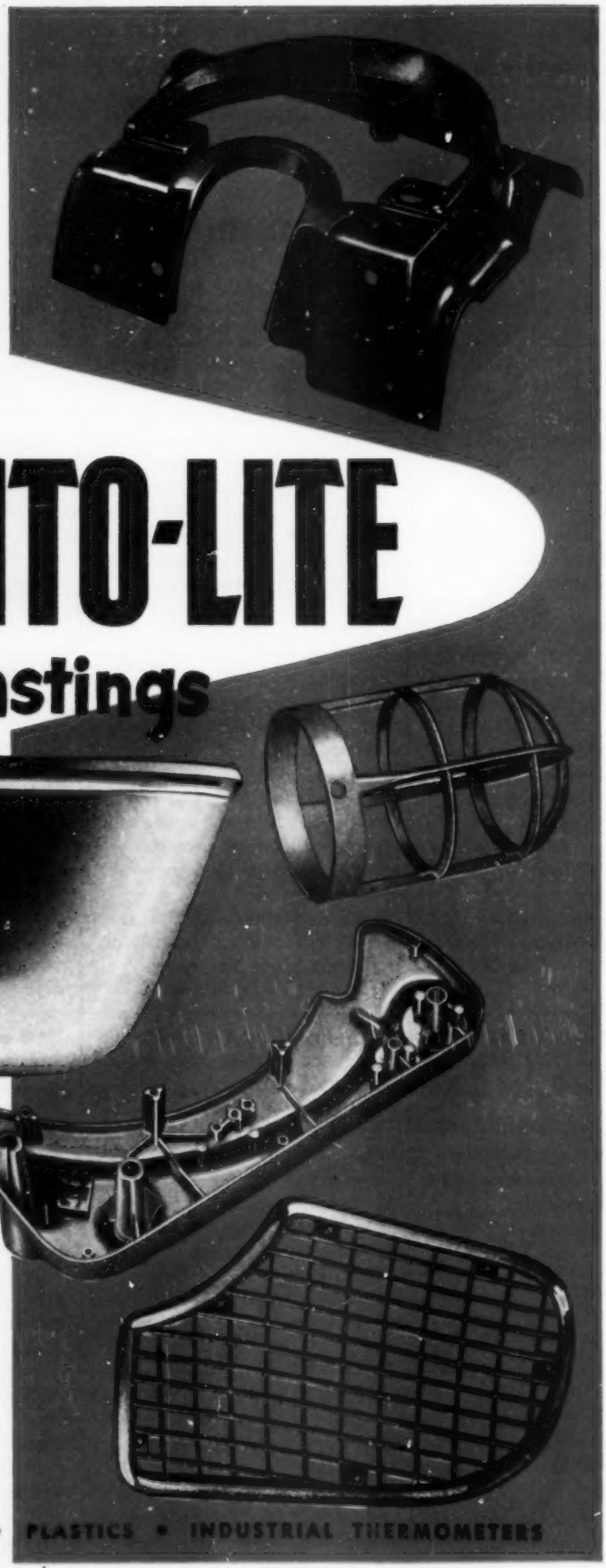

● Many of America's leading manufacturers, producing a wide variety of products, are benefiting from Auto-Lite die cast research, experience and advancement. Such developments as high pressure casting, special alloying practices and improved quality through the "controlled metals process" make Auto-Lite the logical source of supply for precision die castings. Address inquiries to:

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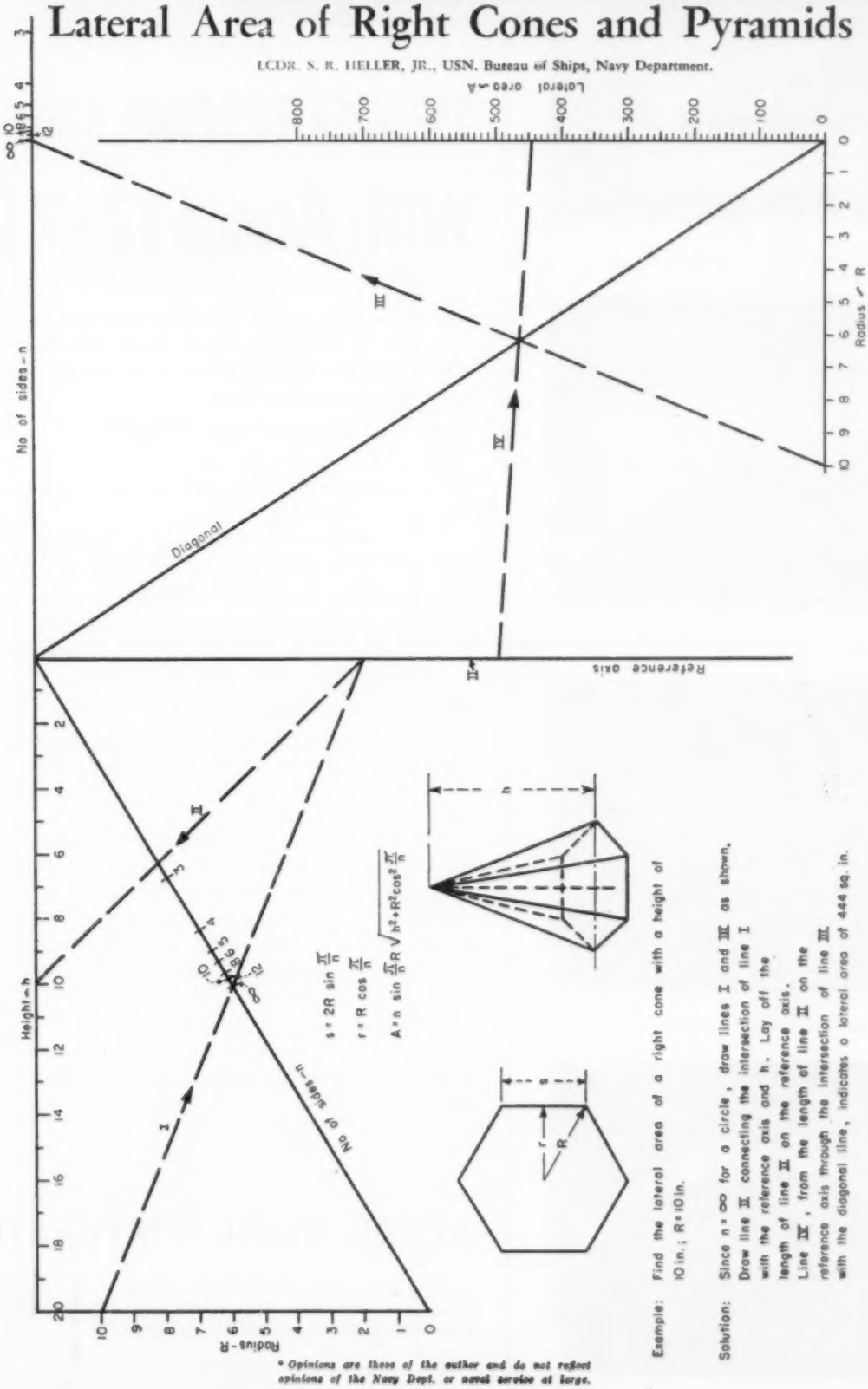
Lateral Area of Right Cones and Pyramids

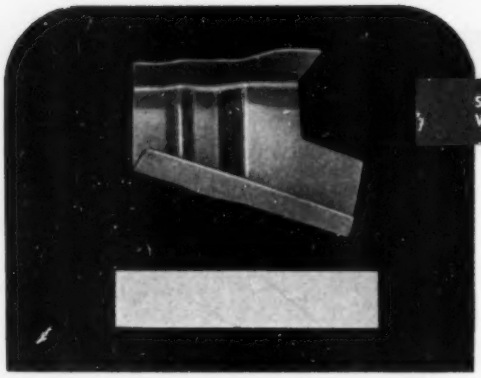
LCDR. S. R. HELLER, JR., USN. Bureau of Ships, Navy Department.



Example: Find the lateral area of a right cone with a height of 10 in.; R = 10 in.

Solution: Since n = ∞ for a circle, draw lines I and III as shown. Draw line II connecting the intersection of line I with the reference axis and h. Lay off the length of line II on the reference axis. Line III, from the length of line II on the reference axis through the intersection of line III with the diagonal line, indicates a lateral area of 444 sq. in.

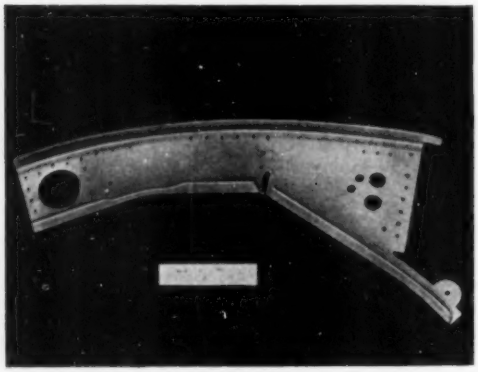
* *Opinions are those of the author and do not reflect opinions of the Navy Dept. or naval service at large.*

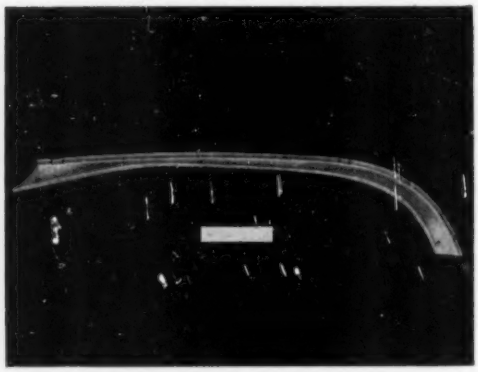


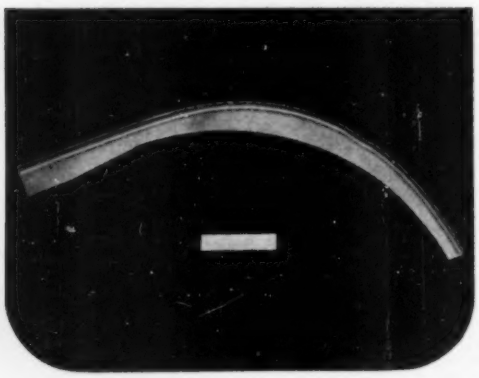
Stainless structural parts for airplanes. White rule represents 6 inches.

50% GREATER DESIGN STRENGTH

With Armco 17-7 PH







Vital formed structurals in certain airplane fuselages formerly were made of Type 301 half-hard temper stainless steel. Here is what the manufacturer gained by changing over to Armco 17-7 PH Stainless Steel:

50-94% INCREASE IN YIELD STRENGTH

Instead of a yield strength in tension of 110,000 psi minimum, he had his choice of yield strengths as high as 165,000 psi minimum in finished parts.

Yield strength in compression could be increased correspondingly from 85,000 psi to as high as 165,000 psi minimum.

23% INCREASE IN TENSILE STRENGTH

Ultimate tensile strength of the finished structural parts could be increased from 150,000 psi minimum to as high as 185,000 psi.

IMPROVED WORKABILITY

Fabrication difficulties were also overcome. Half-hard temper Type 301 must be worked in the hard condition. With an elongation of only 15-18 per cent in 2", it is difficult to form and results are often inconsistent.

On the other hand, Armco 17-7 PH may be worked in the fully annealed condition and hardened by heat treatment *after fabrication*. With an elongation of 20-40 per cent in 2", it will take far more severe forming than Type 301, half-hard. Its high strength is developed through a double low-temperature heat treatment of 1400 F plus 950-1050 F. Scale developed in heat treatment comes off readily in sandblasting.

This is but a thumb-nail sketch of the advantages of Armco 17-7 PH in structural applications. Write for complete information on this precipitation-hardening chromium-nickel stainless steel.

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ARMCO

A Graphical Aid for Combined Stress Problems

JOHN P. HATCH
Mechanical Engineering Department, Thayer School of Engineering

Two dimensional combined stress problems involve the following formula:

$$T = \sqrt{S_s^2 + (S_t/2)^2} \qquad (1)$$

where

S_t = simple direct tensile stress, psi
S_s = simple direct shear stress, psi
T = max. resultant shear stress, psi

When the problem is such that the ratio, $S_s/\frac{1}{2}S_t$ can be computed and the allowable value of T is known, the graphical construction shown in Fig. 1 can be used.

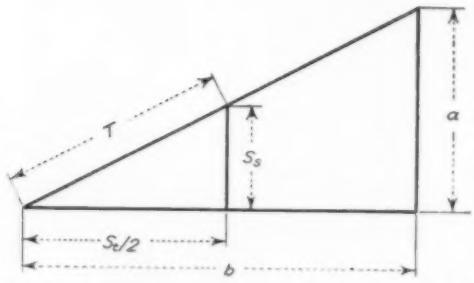


Fig. 1—Construction: Lay off a right triangle with legs a and b such that $a/b = s_s/\frac{1}{2}s_t$. On the hypotenuse lay off T to a convenient psi scale. Drop perpendicular s_s. Using the same psi scale, measure the two stresses, s_s and $s_t/2$.

EXAMPLE: Tension and Shear Loading of Bolt.
Given:
T is not to exceed 7,000 psi
Bolts are loaded as shown in Fig. 2.
PROBLEM: Find bolt diameter required.
SOLUTION:

L_s = shear load per bolt $= \dfrac{3,000}{2} = 1,500$ lb

L_t = tensile load per bolt $= \dfrac{6 \times 3,000}{2 \times 3.5} = 2,570$ lb

a = area of bolt, sq. in.

Then $$\frac{L_s}{L_t} = \frac{1,500}{2,570} = \frac{a\,S_s}{a\,S_t}$$

Thus, $$\frac{S_s}{S_t/2} = \frac{1,500}{1,285}$$

See Fig. 3 for the graphical solution.

The following calculations are not necessary if the foregoing construction is made. In lieu of the construction, the solution is:

$$\tan\alpha = \frac{1,500}{1,285} = 1.168$$

$$= 49.4 \text{ deg (approx)}$$

$$S_s = T \sin\alpha = 7,000 \times 0.759 = 5,313 \text{ psi}$$

This value is satisfactory since it is less than the allowable stress. Based on the maximum shear stress theory of failure, the bolt dia, d, is:

$$d = \sqrt{4L_s/\pi S_s} = \sqrt{\frac{4 \times 1,500}{3.1416 \times 5,313}} = 0.60 \text{ in.}$$

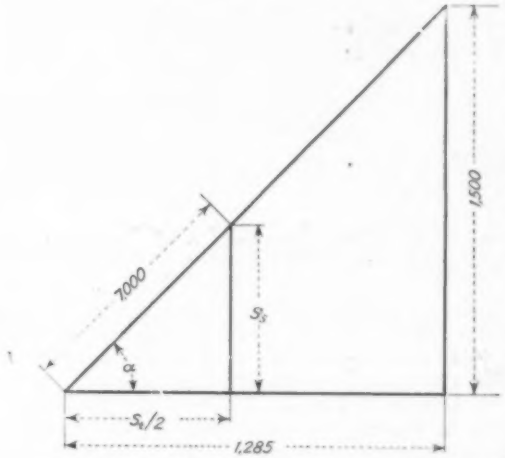


Fig. 3—Legs L_s and $L_t/2$ correspond to a and b in the sample construction. After dropping the perpendicular, s_s and $s_t/2$ are measured with the psi scale used to layout T=7,000 units on the diagonal.

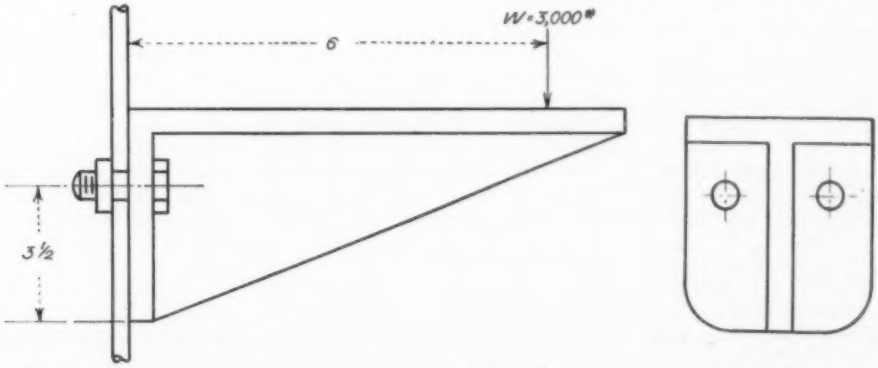
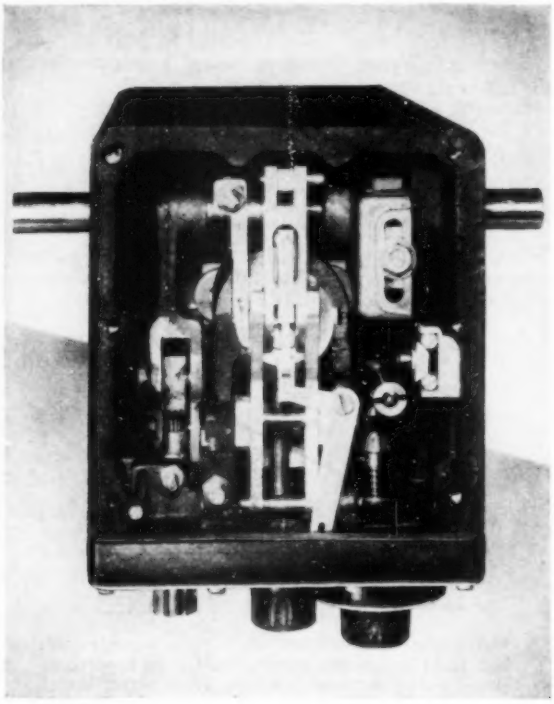


Fig. 2—Bolts in sample problem are loaded as shown. Graphical construction is shown in Fig. 3.

NEW COMPONENTS-



Hydraulic Governor for Diesel Engines

A hydraulic governor for universal application to all types of diesel engines has new features of design to cover a wide range of applications and to improve performance. The necessity of changing governor parts has been eliminated by the use of six adjustments to adapt the units to the particular requirements of the engines on which they will be used.

A self-contained oil supply, a new system of by-pass porting, and elimination of accumulators, avoids pressure exhaustion, and permits effective governing under all speeds and load conditions. The illustrations above show the front and top view of the unit.

A small pilot valve movement results in a small opening of the ports and a corresponding high oil velocity over the pilot valve lands which creates a low pressure area at the lands. This low pressure gives a difference in forces which tend to close the opening of the ports. This force is relatively large compared with the change in force of the flyweights due to a small speed change. It is opposing the action of the flyweights, thus causing "jiggles" in the governor.

The functioning of the by-pass principle is shown in the schematic view of the governor. The gear pump takes the sump oil and builds up the pressure oil. The pressure oil flows around the stem of the pilot valve (1) and out ports *A* and *B*. There is about a 0.012 in. opening on each side of ports *A* and *B*. These openings are larger than the critical openings that give the centering effect. The pressure oil becomes static oil, and exerts an equal force on each side of the servo-piston. The full capacity of the pump is by-passed over the pilot valve lands to the pump. Therefore, there is pressure oil at 100 psi, and static oil at 50 psi, and the pump will be working against only a 100 psi pressure. On speed changes, the pressure oil increases its pressure as the by-pass is limited by the pilot valve movement. On large speed changes when the pilot valve moves enough to close one side of ports *A* and *B*, the oil pressure is limited only by the setting of the relief valve. Therefore, in governing at a fixed load and on small speed changes, the pump is working against a 100 psi head, but on large load changes there is available high pressure oil to restore the engine to operating speed.

With this system, a small pilot valve movement (small speed change) will give a quick response of the servo-piston by increasing the pressure on one side and decreasing the pressure on the other side. It is possible to record the servo-piston travel for 0.0001 in. pilot valve movement. A dial on the panel indicates the position of the servo-piston. This dial is operated by rack (7) and a gear.

Valve (2) is used, forming part of the oil channels from the pilot valve to the servo-piston (3). This valve

works on the by-pass principle and does three things: it is adjustable, by adjusting screw (20), to close off ports *C* and *D*, slowing down the servo-piston speed; it is used as a by-pass valve to give load-limiting; and for positive shutdown of the engine.

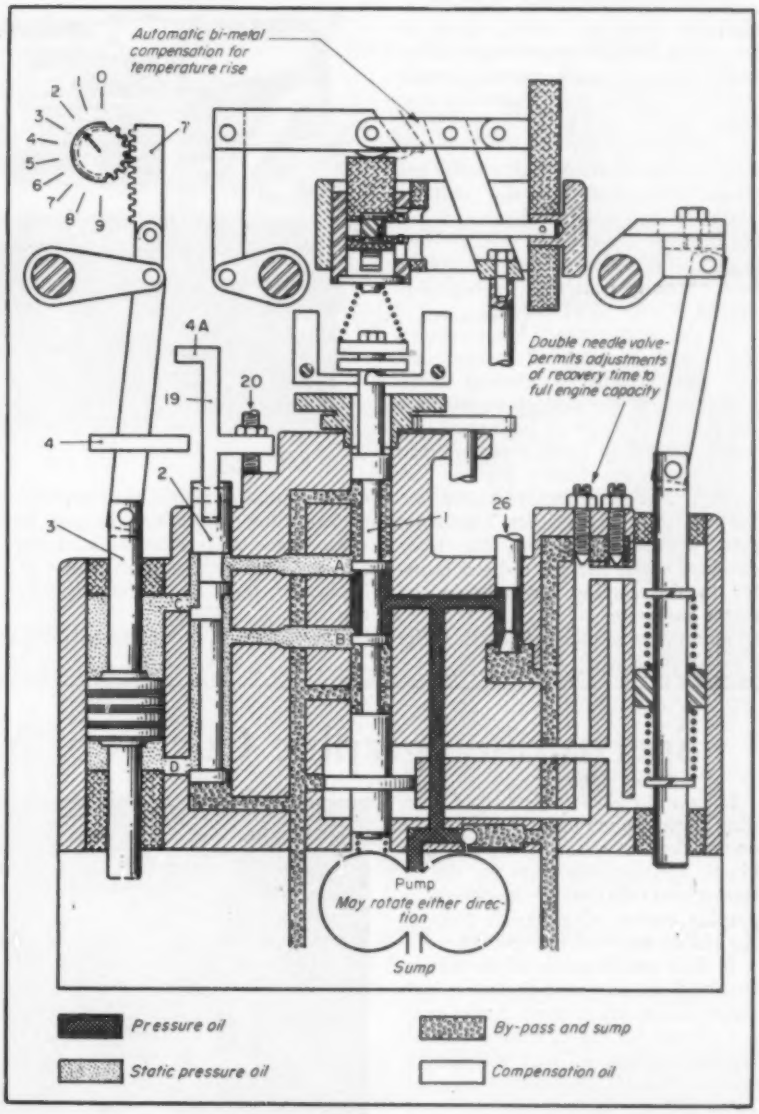
The finger (4) is adjustable on the panel for load limit. The finger is adjusted so that at the position of the servo-piston at which it is desired to limit the load, finger (4) has raised finger (4A) and plunger (2) until there is a hydraulic balance on each side of the servo-piston. The lands of plunger (2) are narrower than the diameter of ports *C* and *D* which gives a bypass of oil over the two lands. When this takes place, the fly-weights move in and the pilot valve is lowered. Any further tendency of the servo-piston to move upward would raise plunger (2), increasing the flow of static pressure oil from port *B* through the lower side of port *C* to the upper side of the servo-piston. Also, the flow of oil from the upper side of the servo piston to the sump is restricted by the closing off of the upper side of port *C*, giving a pressure increase on the upper side of the servo-piston. The static pressure oil for port *B* is restricted by the closing of the upper side of port *D*. The lower side of port *D* is further opened to the sump, giving a reduction in pressure on the lower side of the servo-piston, causing it to move down. The result is a hydraulic balance on each side of the servo-piston, maintaining its position.

Rod (19) extends up through the governor cover. It is held in the down position by a spring, and can be actuated upward, manually, or by other means to act as a positive shut-down. Raising plunger (2) to its extreme up position, closes the upper side of port *C* to the sump and opens the lower side of port *C* to the static pressure oil from port *B*. The upper side of port *D* is closed to the static oil and the under side of port *D* is open to the sump. The servo-piston is forced down, shutting off fuel to the engine.

On diesel turbo supercharged variable speed applications where it is desirable to have a time lapse on going from "no load idling speed" to "full-load, full-speed", a special unit is provided in the governor for adjusting the rate at which fuel is supplied to the engine, regardless of the movement of the manual speed control lever. This is desirable in supercharged diesel engines where the air supply is dependent upon the exhaust. An insufficient air supply, due to a sudden increase in the fuel supply, normally results in an interval of incomplete combustion, and excessive carbon deposits. Through a needle valve, adjustment is made in the control to supply fuel at a rate at which the fuel air ratio is at its optimum value throughout the acceleration process.

When the manual speed control is moved for an increase in speed, a torsion spring imparts torque to a shaft to which are applied linkages connecting with a dashpot piston. The rate of escapement of the torque forces set up within the torsion spring is governed through a needle valve adjustment in the dashpot, which in turn controls the speeder plug movements.

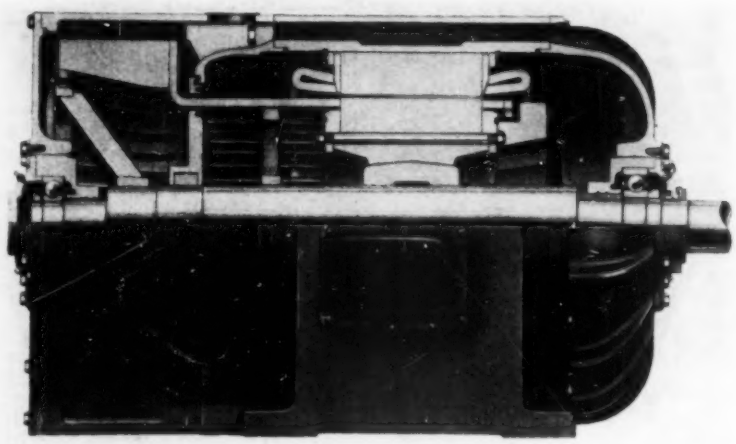
Dale Hydraulic Controls, Inc., 700 South St., Rockford, Ill.



CONTINUED ON PAGE 210

High-Slip Motor For High Inertia Loads

A new totally enclosed, fan-cooled, high-slip induction motor, designed for use in acceleration of high-inertia loads such as punch presses, centrifuges, and hoists, is designated as type KRX, and is said to be as much as 30 percent smaller and 40 percent lighter than conventional totally enclosed fan-cooled high-slip motors. The space and weight reduction, is the result of the motor's new extended-bar design which dissipates the increased heat normally generated by high-slip motors.



In the new motor, low-resistance rotor bars are extended on one end and pass through a rotating baffle plate. Beyond the baffle plate, the bars are brazed to strips of high-resistance metal, shaped to form a radial-blade fan. These fan blades provide the higher rotor resistance necessary for the high-slip characteristics. Therefore, most of the heat from the rotor develops where there is a direct transfer to the cooling air—outside the motor enclosure.

The manufacturers claim that the reduced heating within the motor enclosure allows a normal air gap between rotor and stator to be maintained. This reduces operating costs because there is no loss of electrical efficiency.

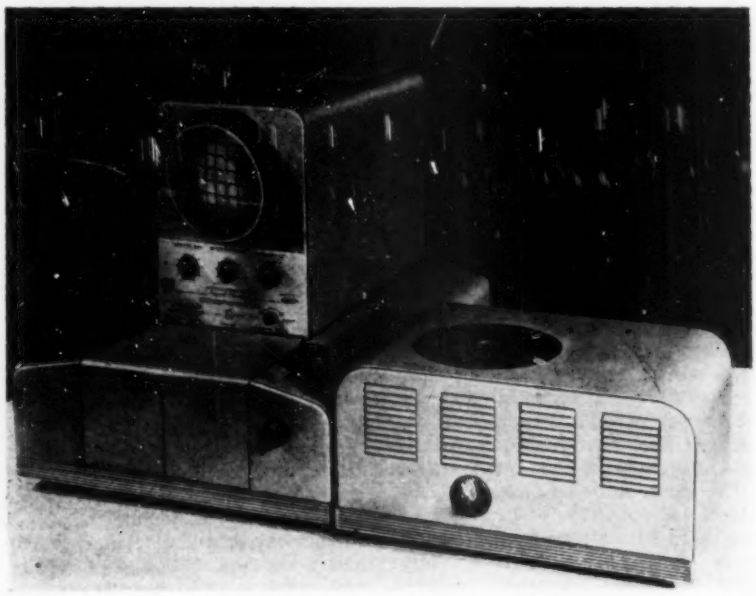
The type KRX motor is available in 30 to 150 hp at 900 and 1,200 rpm, 5-8 and 8-13 percent slip. Voltage ratings are 220, 440, and 550.

For more information on this motor, write to the manufacturer.

General Electric Co., 1 River Rd., Schenectady 5, N. Y.

Spectrophotographic Curves of Materials Shown

Shown at right is a new rapid scanning Spectrophotometer, said to be one of the first commercially available kinetic spectrophotometers for the instantaneous display of spectrophotographic curves of materials through the visible range of the spectrum.



It is a combination of an optical spectrophotometer and electronic indicating device which traces curves at 60 per second on the face of a cathode ray tube against a linear wavelength-percentage grid. Transparent materials up to 100 mm in thickness can be accommodated. Spectrophotometric reflectance curves may be obtained from opaque materials of approximately 1 sq. inch. The rapid scanning spectrophotometer is adaptable to the study of rapid color changes, and offers possibilities for monitoring a flowing liquid. As many as 10 curves may be superimposed in one picture together with zero line, 100 percent line, and wave length standardizing filter reference. Time lapse photographs offer a way of obtaining a permanent record of color changes in sequence.

American Optical Co., Instrument Div., Buffalo, N. Y.

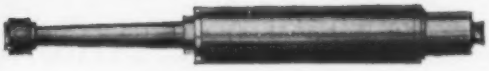
CONTINUED ON PAGE 212

It's the SPINDLE That Does The Work

on SURFACE GRINDERS

specify **POPE P32-T** Direct Motorized Cartridge Type with strong, oversize 1 HP, 3450 RPM totally enclosed motor.

POPE

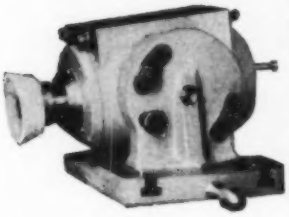


on INTERNAL GRINDERS

specify the NEW series of **POPE** belt driven, cartridge type Precision Internal Grinder Spindles, up to 54,000 RPM, with chrome plated, stationary cap in place of the old, revolving type.

It's the SPINDLE That Does The Work

on TOOL and CUTTER GRINDERS



specify **POPE P-6651-A** 3600-RPM Motorized Tool and Cutter Grinder Head with angular adjustment in a vertical plane.

POPE

on GRINDING, MILLING, BORING

specify **POPE P-2500** Heavy Duty Direct Motorized Spindle for grinding, milling, boring —¾ to 100 HP.

It's the SPINDLE That Does The Work

on WHEEL HEADS

specify **POPE P-12004** Heavy Duty Vee-Belt Driven Machine Wheel Head for up to 4000 RPM— ½ to 50 HP.

POPE

on 6" x 18" SURFACE GRINDERS

specify **POPE P-6351** High Speed Vertical Spindle Attachment for 6" x 18" Surface Grinders — 15,000 RPM.

It's the SPINDLE That Does The Work

★ *For complete specifications, prices and delivery estimates on these and the many other Precision Spindles on which the quantity and quality of a machine's production so largely depends, get in touch with*

No. 90

POPE

POPE MACHINERY CORPORATION
ESTABLISHED 1919
261 RIVER STREET • HAVERHILL, MASSACHUSETTS
BUILDERS OF PRECISION SPINDLES

Fail-Safe, Automatic Defrosting Switches

Made in three types, to suit a wide range of applications, new automatic defrosting switches are said to "police" their own internal mechanism as well as the operation of the refrigeration system.

The series TP-300 features a time initiated, pressure-terminated control of the defrost cycle, in which adjustable trip pins on a 24-hour clock dial start the cycle, while pressure in the refrigeration system terminates it.

In the TT-300 series, the defrost cycle is also time initiated, but is terminated by a rise in temperature in the system. The TS-300 series also initiates defrosting by a time setting, but permits termination either by a remotely located pressure switch or temperature controller, or both.

According to the manufacturers, the advantage of the new switches is that they eliminate all guesswork in establishing the proper length of the defrost cycle. They automatically compensate for seasonal variation, atmospheric changes, usage habits and practically eliminate human errors in judgment. They may be used with all methods of defrosting in commercial use, whether electric heat, hot gas, reverse cycle or straight shutdown. An inner row of adjustable pins on the clock dial will automatically return the system to normal operation should a pressure or temperature bellows fail after starting the defrost cycle. The switch tripping mechanism is so designed that, should the clock motor stall or stop at the start of a cycle, the cycle will be terminated normally by the temperature or pressure control.

A feature of the switch design is that it will also return the system to normal operation should high temperature or high pressure in the system prevent starting of the defrost cycle. And, if ambient temperature conditions prevent the pressure bellows or control from terminating the cycle normally, defrosting will be stopped mechanically by the inner row of adjustable trip pins on the dial.

All models are listed with contact ratings of 3,000 watts.

One hp, 115 or 230 volt units are available for 25, 50 or 60 cycle current. The actuating bellows which terminate the defrost cycle are designed with a test pressure of 200 psi, and have an operating range up to 150 psi. The TP-300 series has a standard operating range adjustable from 30 to 55 psi. Special bellows are available for F-22.

Dials on all series are adjustable from 1 to 8 defrost cycles per day, and these may be set to start at any hour of the day or night.

Paragon Electric Co., Two Rivers, Wis.

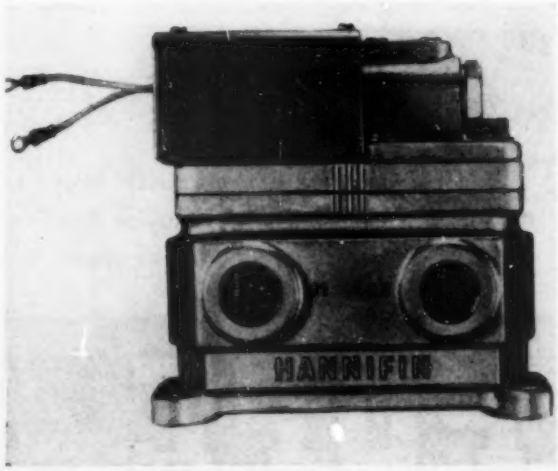
Four-Way Valve Is Pressure Operated

The series BB 4-way valve in a new P-M line of Pilot-Master valves, consists of two series B 3-way pilot-master valves in one common body, with internal coring so arranged that one valve operates normally closed while the other operates normally open.

The main or master valve portion of these 4-way valves comes in three different sizes, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{3}{4}$ in., and the two piston-poppet assemblies, the only moving parts of the main portion of the valve, are identical for all three sizes. They both fit in replaceable cartridges, identical with the cartridge used in like sizes of the 2- and 3-way valves.

Also, one size of pilot head fits all three sizes of master valve. The series BB-2 pilot head, shown in the illustration uses the same industrial quality solenoid used with the series B-2 head for the 2- and 3-way valve. Speeds to 600 cycles per minute are said to be possible with this combination. Also available is a series BB-4 pilot head, with two solenoids, for momentary contact operation.

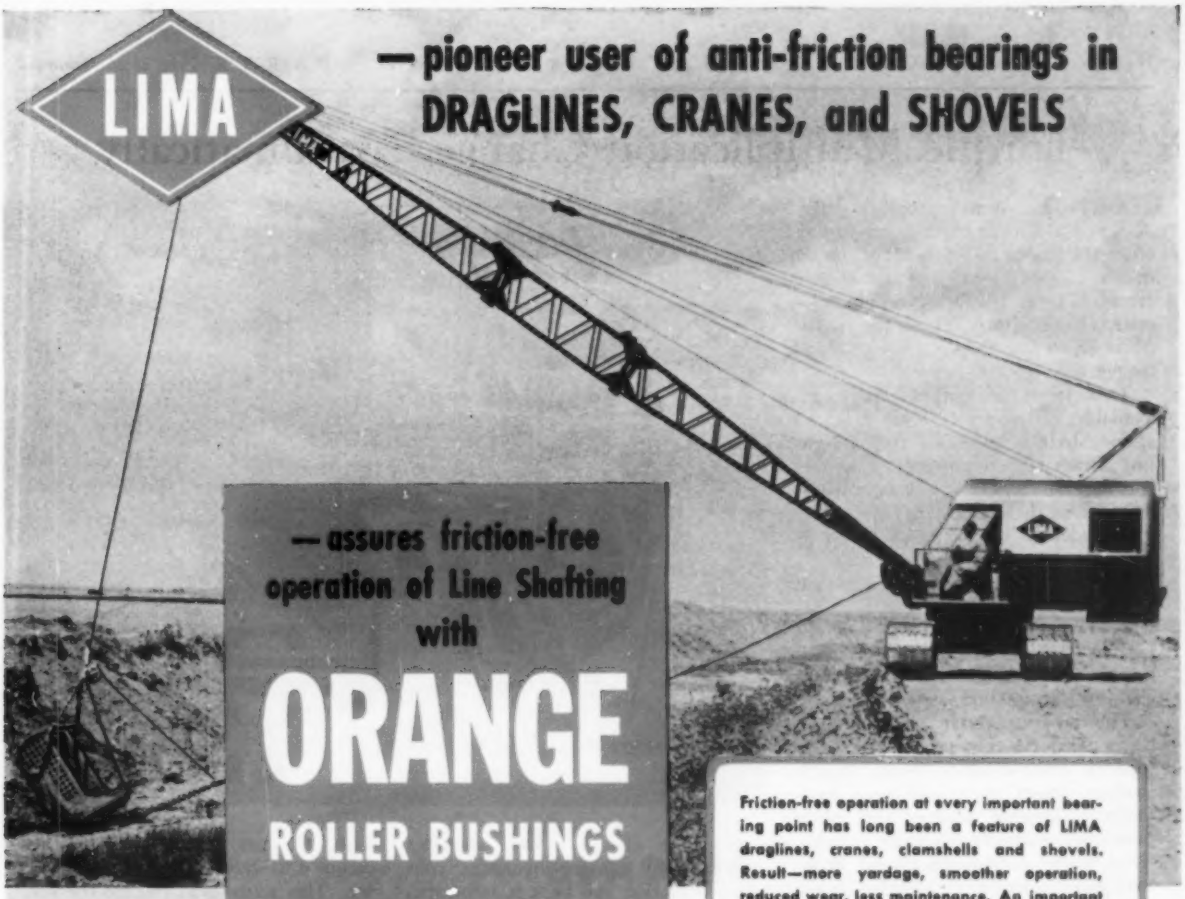
Hannifin Corp., 1126 S. Kilbourn Ave., Chicago 24, Ill.



CONTINUED ON PAGE 214

LIMA

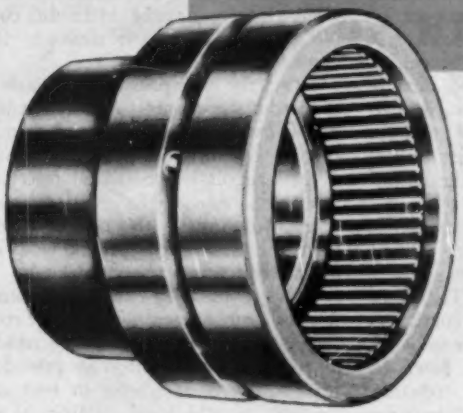
— pioneer user of anti-friction bearings in DRAGLINES, CRANES, and SHOVELS



— assures friction-free operation of Line Shafting with

ORANGE
ROLLER BUSHINGS

Friction-free operation at every important bearing point has long been a feature of LIMA draglines, cranes, clamshells and shovels. Result—more yardage, smoother operation, reduced wear, less maintenance. An important contribution to this friction-free designing, is the use of Orange Roller Bushings in the line shafting of many models, to eliminate friction and wear under heavy shaft loads.



Like LIMA engineers, hundreds of others have found it pays to friction-proof rotating or oscillating parts with Orange Roller Bushings. Whether it's an 8" shaft or a small gear box—heavy load or high speed—Orange Roller Bushings are the most compact, economical, long-life protection for critical wear spots.

Orange Roller Bushings provide exceptionally high load carrying capacity in small space. They stand up in heaviest equipment, yet are precision-running to satisfy the most exacting requirements. Extreme precision standards provide closer internal running clearances, which minimize possibility of misalignment of rollers.

- **Orange Roller Bushings are available in a full range of sizes from ½" to 8" shaft diameters. Also double and triple row types for special applications.**
- **Send drawings or details of needs for suggestions. Engineering representatives are conveniently located to work with you on any bearing installation.**

Write for Engineering Data Book showing sizes, capacities, installation data, etc.

ORANGE

ORANGE ROLLER BEARING CO., Inc. 551 Main St., Orange, N. J.

Torque Multiplication Changed Automatically

A torque converter coupling drive, designed to handle engines developing from 180 to 225 foot pounds of torque in the 2,000-2,200 rpm or higher range, has the advantage of an automatic change from 2:1 torque multiplication to 1:1 coupling operation as torque requirement demands.

Two types of output shafts are available. In model 12-S, a 1½ in. 10 spline shaft is provided for straight line drives with a universal joint. If it is necessary to use sprockets, pulleys, or gears on this model, they should be independently supported in outboard bearings.

The model 12-A has a flanged output shaft and an SAE no. 3 flywheel housing at the rear. This design permits the installation of a second flywheel, automotive clutch and mechanical transmission.

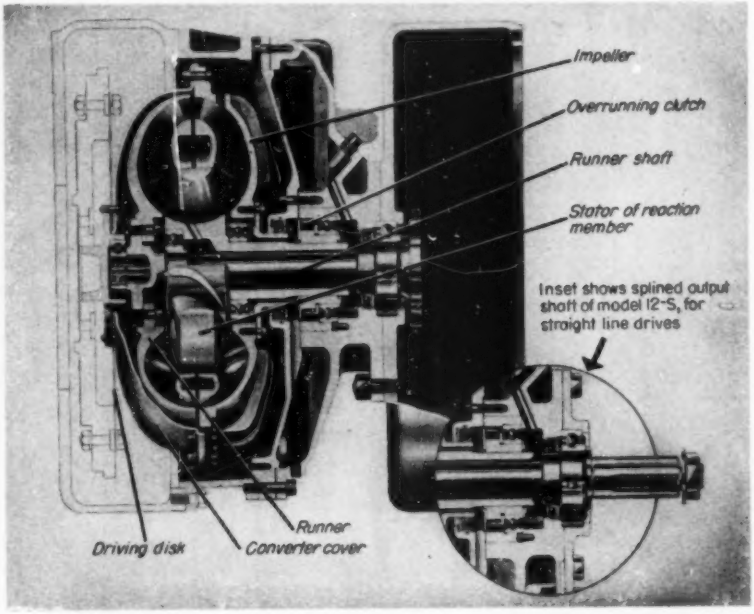
The new converter couplings are being used on tow trucks, front-end loaders, route-delivery trucks, travel-loaders, hoists, yard and mine locomotives, logging yarders and other industrial materials handling installations where start-and-stop, and heavy load pickups are hard on engine, gears, drive lines, and axles.

Features of this torque converter design are: no external oil pump or piping for normal operation; low oil pressure which protects seals; self-contained cooling system under normal operating conditions; fits commercial engines with SAE no. 3 flywheel housings; flexible driving disk which corrects for slight misalignment.

This converter is designed to handle engines developing from 180 to 225 ft-lbs of torque. In order to permit operation in the coupling range part of the time to assist cooling, use with engines having a top speed of 2,000 to 2,200 rpm or higher is recommended.

The maximum torque multiplication of this converter is approximately 2 to 1. However, this ratio is obtained only when the output shaft is not turning.

The industrial torque converter is a single stage design with three simple elements consisting of: (1) impeller or pump; (2) runner; and (3) reaction member or stator. The reaction member is mounted on an overrunning clutch which permits rotation with the runner while in coupling range; making the unit of a two phase design. The change from converter operation to straight hydraulic coupling operation and back is automatic, depending only upon the amount of torque required in the drive line.



Power is delivered from the engine flywheel through the thin, flexible driving disk and converter cover to the impeller. Rotation of the impeller throws the oil into the vanes in the runner which is splined to the output or runner shaft.

The oil in the converter, operating in a close circuit, leaves the runner at the inner edges of the vanes and enters the reaction member. The vanes in the reaction member are curved so as to turn the oil back into the impeller in the direction of original flow. In the converter range, the reaction member is locked to the housing through the overrunning clutch. Thus, the thrust reaction from changing the oil direction by the reaction member vanes is taken by the housing. This thrust load imparted to the oil stream creates the torque multiplication in the unit.

As the torque requirement on the runner shaft is reduced, the runner speed will increase to the point where the oil, coming out at the inner edges of the vanes, will strike the reaction member vanes on the reverse side. The overunning clutch on which the reaction member is mounted will then permit it to start rotating with the runner. This action will change the converter into a straight hydraulic coupling which does not multiply the engine torque.

Since the oil pressure is slightly higher in the reaction member vanes, where its direction is changed than it is at the entrance to the impeller vanes, by-pass circulation to the oil reservoir is created through the small oil passages. Cooling of the oil is accomplished by radiation from the walls of the converter and reservoir.

This self-contained radiation system has sufficient capacity to cool the converter under normal operating conditions. However, openings are provided for connecting a radiator or heat exchanger, if additional cooling is required. When a radiator or heat exchanger is used an internal oil passage must be partially plugged. The maximum operating temperature should not run over 250 F.

The oil capacity is 17½ pints, and a straight mineral oil, SAE 10 weight, with no additives or detergents is recommended. The oil pressure is approximately 15 psi. The only service requirement is a periodic check of the oil level.

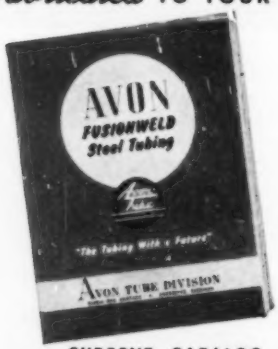
Fuller Mfg. Co., Transmission Div., Kalamazoo, Mich.

CONTINUED ON PAGE 217

Tubing ...HIGH TENSILE, SOLID WALL

FOR THE *Toughest* BENDING, FLARING, SWAGING, HI-PRESSURE SPECIFICATIONS

3/16" O.D. TO 5/8" O.D.
PLAIN OR TERNE COATED
***Fabricated* TO YOUR PRINT**



CURRENT CATALOG ON REQUEST

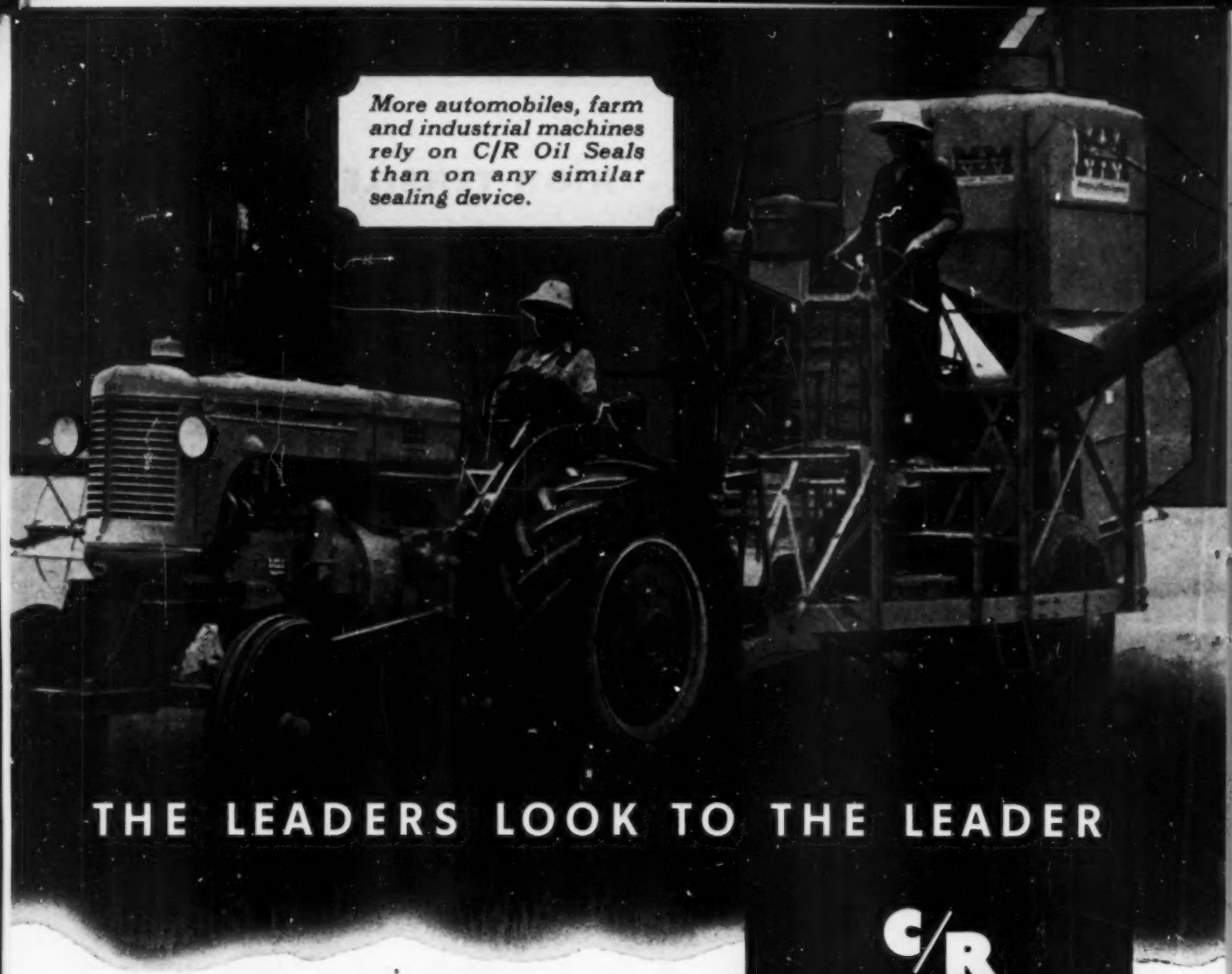
● Avon Fusionweld—thin wall steel tubing—serves a constantly expanding variety of industrial needs . . . is fusion welded under a new, rigidly controlled hi-cycle process to insure uniformity of wall strength and structure . . . meets the highest standards for tensile strength, ductility, resistance to fatigue and pressures.

Available in straight lengths or continuous coils. May be specified "as welded" for miscelianeous commercial purposes; "hard drawn" in machining operations where threading, knurling, piercing, are specified; "annealed" to serve the most difficult problems of bending, flaring, swaging, beading and coiling without cracking, tearing or checking—to carry fluids under high pressures.

Widely used in automotive, refrigeration, air conditioning, space heater, stove, electrical, radio, TV and toy manufacturing industries. Post yourself on the superior economy and performance of Fusionweld—truly the tubing with a future! Let Avon help you find a more suitable answer to your tubing problems.

FUSIONWELD...THE TUBING WITH A FUTURE

AVON TUBE DIVISION HIGBIE MFG. COMPANY ROCHESTER, MICHIGAN



THE LEADERS LOOK TO THE LEADER

C/R Oil Seals

Minneapolis-Moline uses

In the Minneapolis-Moline harvester or combine shown, two C/R Oil Seals are used at points requiring an oil flooded bearing on one side and a dry brake on the other. That guarantees long bearing life and proper brake functioning at all times.

This job has two large heavy duty brakes that can be operated independently or together. If one wheel slips, it can be locked and all the traction transferred to the other.

Minneapolis-Moline says this double C/R Seal is the most interesting application they have in their whole line of products. It protects a vital point in this tractor.

This is another example of the leaders looking to the leader, for research, engineering and manufacture of the highest type. If you have a particularly tough lubricant sealing or dirt exclusion problem, put it up to Chicago Rawhide engineers.

C/R, the most widely used oil seals, are stocked in over 1,800 sizes covering 16 different types for immediate delivery. Our free handbook, "Engineering with C/R Oil Seals" belongs in your files. Allow us to send it to you.

75 C/R

CHICAGO RAWHIDE MANUFACTURING CO.

1299 Elston Avenue OIL SEAL DIVISION Chicago 22, Illinois

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Boots, diaphragms, packings and other products that give dependable service under difficult operating conditions.

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Manufactured and distributed in Canada by Super Oil Seal Mfg. Co., Ltd., Hamilton, Ont.

Pressure Transmitter Used With Liquid Or Gas

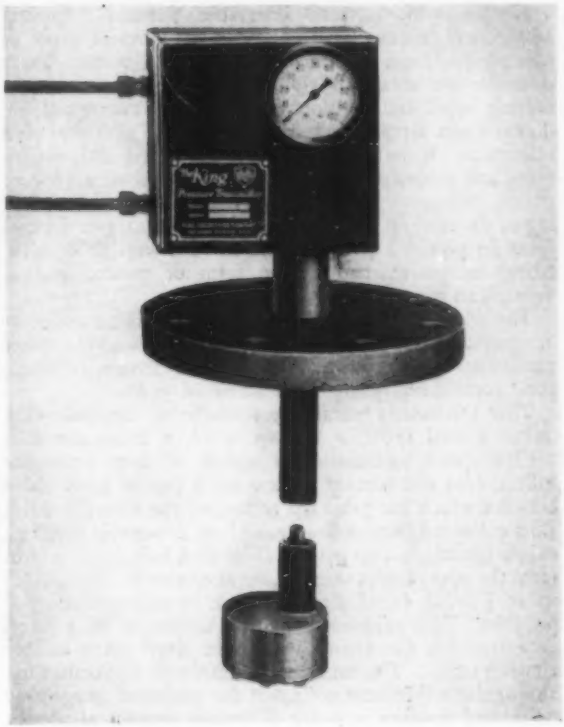
A Pressure transmitter, used for measuring the pressures of liquid or gases where a seal is needed between the gaging system and the fluid meausred, has a diaphragm that is exposed to the fluid to be measured and can be used with almost any fluid. The pressure of the fluid on the outer side of the diaphragm is continuously and automatically balanced by the pressure of air supplied to the inner side; and this air pressure is transmitted through a pipe or tube to the receiver.

Various types of receivers can be used, such as hydrostatic gages, manometers, or pneumatically-actuated recorders; and two or more receivers at different locations can be used with the same transmitter. When used in liquid-level measurement, the receiver can be graduated to show the depth, weight, or volume of liquids in vented or pressurized tanks. The linear response of the transmitter permits readings accurate to plus or minus $\frac{1}{4}$ in. of water on vented tanks, and plus or minus $\frac{1}{2}$ on pressurized tanks.

The pressure transmitter is available with flange mounting, for use with the diaphragm inside the tank, and with a union connection, for use with the diaphragm outside the tank. Both types can be furnished for mounting at the top, bottom, or side of the tank. In addition, a combined liquid-pressure and equalizer unit is available, for measuring liquid in pressurized tanks.

Standard pressure transmitters have a pressure range of 0 to 45 psi, and withstand overpressures of 250 psi. They require a supply of clean dry instruments air at 70 psi or higher. Air consumption is less than 4 cubic feet per hour.

King Engineering Corp., Ann Arbor, Michigan



Light Weight Solenoids Developed For Aircraft

These miniature solenoids are specifically designed for an accurate actuating force where aircraft quality solenoids are required. Model SD-128, shown at left, is a pull-type solenoid. It is a continuous duty solenoid designed to pull 4 lb, 0.062 in. at 24 v d-c.

The push type solenoid, model SD-73, shown at right, will push 18 lb, 0.025 in. at 24 v d-c. This solenoid is practical for use in instruments and in other applications where relatively short strokes are required. The miniature push-type solenoid also features an adjustable stroke. The stroke may be adjusted with an accuracy of ± 0.002 in. by means of a threaded plunger. In addition, the plunger shaft may be re-positioned by as much as 0.125 in. from its normal position. This allows positioning of the solenoid stroke in relation to the mating parts of the product on which it is used.

Although these miniature solenoids have been service tested on aircraft valves, the manufacturer claims that the solenoids have other uses where positive actuation is required in a small space. Solenoids of the same shape shown in the illustration are availble in a range of sizes and capacities to meet specific requirements.

PSP Engineering Co., 8420 Otis St., South Gate, Calif.

CONTINUED ON PAGE 218

Instrument Has Wide Measuring Range

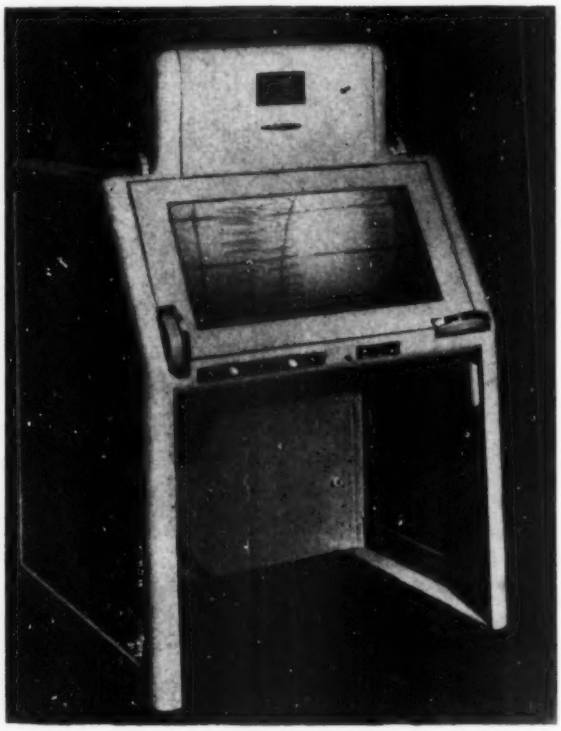
Known as the universal Telereader, this unit is capable of accurately measuring distances on all types of paper or film records from 16 mm up to 12 in. in width. These distances are measured along two orthogonal axes permitting rapid transmission of data from the records to digital form representing deflections from arbitrary fixed references. It has the necessary equipment for magnifying and projecting a section of the record on a viewing screen. Accessory equipment is available to permit recording of the reading cross wire positions in binary or decimal form on punched cards suitable for use with IBM calculating equipment, and in the form of printed records through an electric typewriter.

The telereader is capable of handling either translucent or opaque records, and shall be capable of handling either continuous roll records up to 100 feet in length, or single sheet records not greater than 12 in. in width.

This mechanism consists essentially of the following units: a feed spool, a take-up spool, a drive motor, a variable-speed transmission, a system of drive and idler rollers, feed and take-up guides, and a pair of glass plates between which the projected section of the record is held. This entire mechanism is mounted on a movable carriage, whose lateral position may be controlled by a hand control from the operating position. Lateral motion of the carriage up to ½ in. in either direction from its center position is possible. This adjustment permits alignment of a reference trace on the record with some fixed point on the viewing screen. The entire record transport mechanism has an angular adjustment such that the projected image may be rotated through ±5 deg to permit angular alignment of each section of the record during reading.

It is possible to drive continuous roll records past the projection section in either forward or reverse directions. The range of record speeds is from ½ in. to 100 feet per min in the forward direction, and from 10 to 100 feet per min in reverse. Starting, stopping, and speed control of the record drive motor is accomplished by a foot pedal.

Three interchangeable projection lenses permit image magnification selections according to the type of record being read. These lenses have focal lengths of 13.6 in., 10 in., and 4 in., giving magnification of approximately 2X, 4X and 11X, respectively. In order to change magnification, it is necessary only to interchange the lenses by means of mounting brackets provided with each lens.



The rotating pulley shafts driving the cross wire system have digitizing reading heads. One revolution of the cross wire drive shafts corresponds to 5 in. of wire travel in both axes, and the reading heads provides 2,000 counts per revolution of these drive shafts. This will result in a measuring accuracy of 0.0025 in. of wire travel per count, and distances measured per count on the record shall correspond to approximately 0.001 in. for a magnification of 2X, 0.0006 in. for a magnification of 4X, and 0.0002 in. for a magnification of 11X.

The telereader operates from 115 v a-c, 60 cycle source, at 800 watts. Dimensions are 36 in. width, 36 in. in depth, by 56 in. high. Weight is 500 pounds.

Telecomputing Corp., 133 E. Santa Anita Ave., Burbank, Calif.

THE DYNA-SEAL, a new, face-to-face seal comprises a synthetic rubber sealing member bonded to a steel ring and is used for sealing flat surfaces, bolt heads, rivet heads, flanges and special fittings. No grooves are required. The device seals all pressures against water, all types of petroleum products, and other fluids and gases. Available for bolt sizes of from 0.190 in. to 1.125 in. O.D. Precision Rubber Products Corp., Dayton 7, Ohio.

A NEW DIODE CLIP that permits quick, easy insertion and removal of diodes, will accommodate most types of diodes now in use. The clips require no rivets or other fasteners for mounting and are pressed into a hole on the diode board. Spring tension holds the diode in the clip, and a special plating gives good surface contact. Also facilitates preventive maintenance tests. Computer Research Corp., 3348 W. El Segundo Blvd., Hawthorne, Calif.

A NEW AIR DRY LUBRICANT, may be sprayed or brushed on, and has good lubrication characteristics at temperatures from —70 to 300 F. It may be applied to steel, iron, stainless steel, lead foil, aluminum, brass, wood, cork, or other materials, and is resistant to hydraulic fluids, gasoline, lubricating oils, or water. Recommended for hydraulic cylinders, gears threads, and floats. Electrofilm Corp., 7116 Laurel Canyon Blvd., N. Hollywood, Calif.

CONTINUED ON PAGE 220

LOCKED FOR KEEPS!

Standard

Locknuts and Lockwashers can be relied upon for precise, solid locking *every time.* There's no guesswork with Standard. Manufactured by skilled craftsmen to SAE and ABEC specifications, Standard locknuts and lockwashers are known for rugged wear and dependable service. Choose Standard for the job and you can be *sure* that bearing assemblies will be held firmly in position . . . and will *stay* that way!

Our complete stock includes all regular sizes . . . your guarantee that your order will receive prompt attention. There are no costly shipping delays when you deal with Standard.

Call on us, too, for specially designed locknuts and lockwashers. Just send blueprints of the special locknuts and lockwashers you require along with any necessary information to Standard. We'll send you an immediate quotation.

For locknuts and lockwashers, the *quality* name is Standard.

You'll want Standard's informative Bulletin No. 30. Write for it today.

STANDARD Locknut and Lockwasher, Inc.
510 NORTH CAPITOL AVE. • INDIANAPOLIS 4, INDIANA

Electronic and Chemical Mercury Vapor Detectors

Two redesigned portable mercury-vapor detectors, the type A electronic top, and the type B chemical, for indicating concentrations of mercury which could be harmful to industrial workers, can be used by manufacturers of: electrical apparatus, instruments, bulbs and glassware, fur, salt, rubber and by the chemical, metal mining, and smelting industries.

The electronic instrument is designed to give an instantaneous indication of mercury vapor by resonant absorption of ultraviolet energy. It will give readings ranging from 0.01 to 3.0 milligrams of mercury per cubic meter of air, and offers good operational stability independent of line voltage. This is possible because of an additional photo tube in a bridge circuit which measures the visible light, thus maintaining the bridge balance although the line voltage may vary.

The chemical-mercury-vapor detector operates on the principle that activated selenium sulphide, deposited upon a thin sheet of paper, will darken in the presence of mercury. It is designed for continuous monitoring and will indicate as little as 0.10 milligrams of mercury per cubic ft. of air in two hours, the toxic limit for continual breathing of mercury vapor.

The new chemical model has an increased sensitivity factor of approximately four, and its accuracy of determination has been increased over the earlier model by use of a thermoswitch and heater which holds the air sample constant. For good results, a blower is used to get a constant, positive air flow over the indicator paper.

General Electric Co., 1 River Rd., Schenectady, N. Y.

Thread Protectors Fabricated to Close Tolerances

Custom-fabricated thread protectors for the protection of external and internal threads and surfaces on machined parts are made of kraft paper, fish paper, cellulose acetate or combination, and can be had imprinted with the part number, or the name and address of the parts manufacturer. Acid free and non-corrosive, they can be used to keep out oil and grease, or can be used as lubrication retainers. The thread protectors are expendable when used for shipment or delivery, but for storage or intra-plant protection, special materials can be used to withstand repeated handling.

Precision thread protectors are available in practically any size or shape and can be formed, crimped, or perforated to fit irregularly shaped parts. They are spirally wound by a process which permits maintenance of tolerances within 0.003 inch, resulting in a snug fit. For oil-resistant applications, protectors are resin treated. In cases where visibility is desired, cellulose acetate winding is used.

Precision Paper Tube Co., 2035 W. Charleston St., Chicago 47, Ill.

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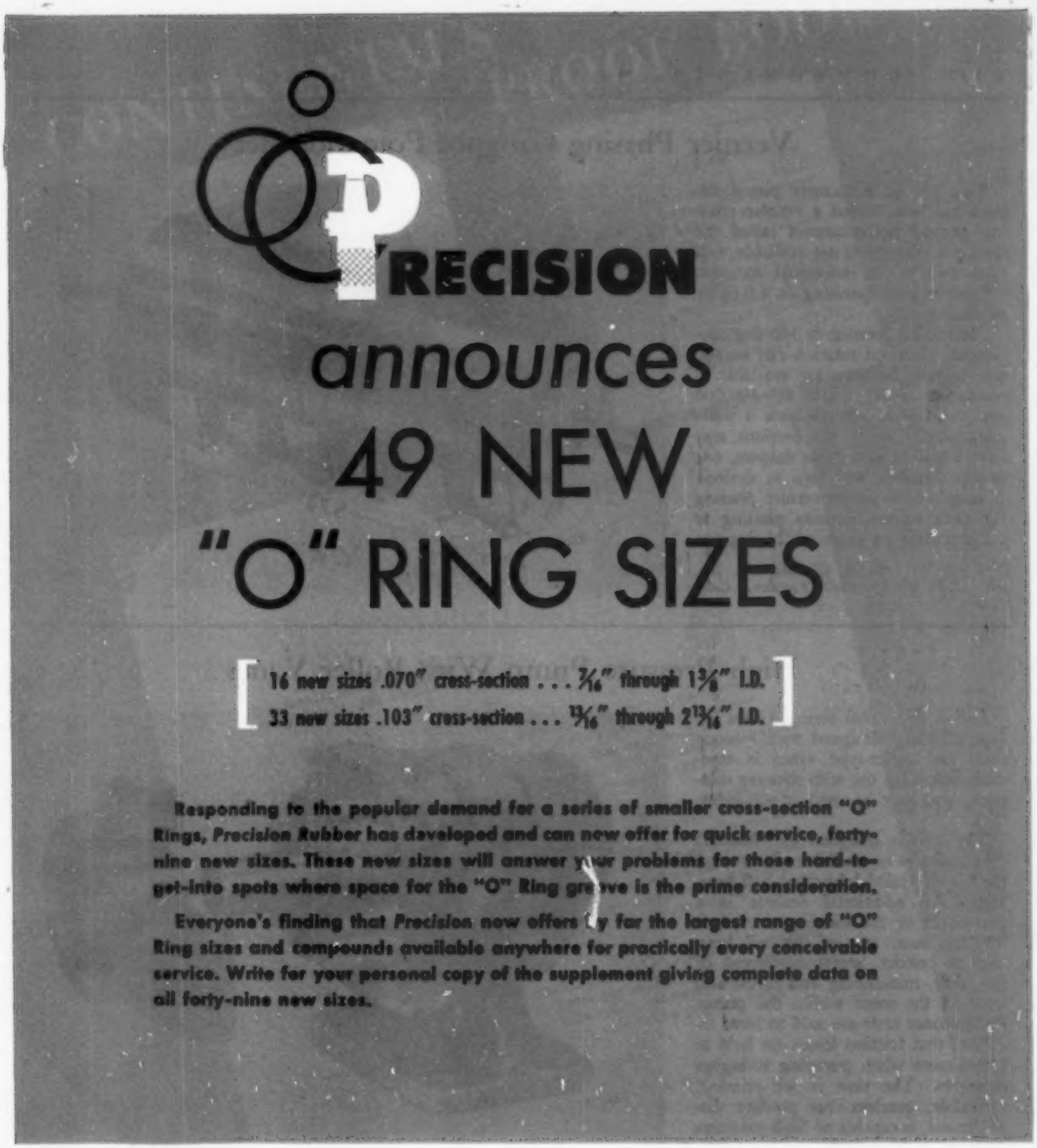
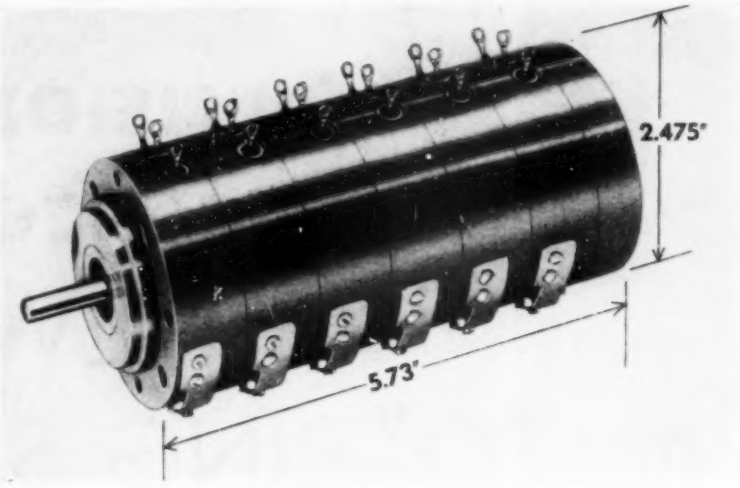

PRECISION
announces
49 NEW
"O" RING SIZES
16 new sizes .070" cross-section . . . 7/16" through 1 3/8" I.D.
33 new sizes .103" cross-section . . . 13/16" through 2 13/16" I.D.
Responding to the popular demand for a series of smaller cross-section "O" Rings, Precision Rubber has developed and can now offer for quick service, forty-nine new sizes. These new sizes will answer your problems for those hard-to-get-into spots where space for the "O" Ring groove is the prime consideration.
Everyone's finding that Precision now offers by far the largest range of "O" Ring sizes and compounds available anywhere for practically every conceivable service. Write for your personal copy of the supplement giving complete data on all forty-nine new sizes.
Precision Rubber Products
CORPORATION
Specialists in "O" Rings and Dyna-seals
Dept. 3, Oakridge Drive, Dayton 7, O. • Canadian Plant at: St. Therese de Blainville, Quebec

Vernier Phasing Gangpot Potentiometer

To a line of instrument potentiometers has been added a vernier phasing ganged potentiometer called the Gangpot. Gangpots are available with from two to six individual sections; a 6-section unit operating on 1.5 oz-in. of shaft torque.

Mechanical rotation is 360 deg continuous; electrical rotation may be 360 deg or less. Sections are available in resistances from 2,000 to 300,000 ohms and each will dissipate 4 watts continuously at 25 C. Sections may have linear or non-linear outputs, one or two brushes, and taps as desired. A simple screwdriver vernier phasing for each section permits phasing to 0.2 deg over an angle of 22 degrees.

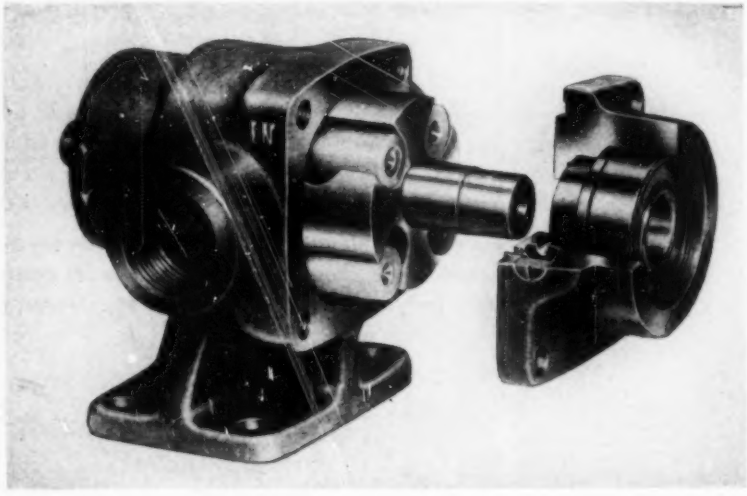
G. M. Giannini Co., Inc., 254 W. Colorado, Pasadena, Calif.



High Pressure Pump With Roller Vanes

Called the 4,000 series, a new industrial pump designed with a scoop rotor and roller-type vanes is especially suited for use with abrasive solutions, and may be used in all industries.

The unit is designed to withstand continuous heavy radial loads through the use of sealed lubricated ball bearings. An additional feature is a pressed fit of the stainless steel shaft into the inner race of the ball bearings to restrict lateral movement of the rotor, minimizing end thrust and wear of the rotor within the pump. Performance tests are said to have indicated that friction losses are held to a minimum when pumping at higher pressures. The unit is self-priming, reversible, gearless, has positive displacement, is capable of high pressures up to 40 or 50 pounds, and has a self-contained unit type seal.



The 4,000 series roller pump is available in cast iron or Ni-Resist and features Nylon or Hy-Car rubber rollers, self lubricated by water and abrasive resistant. It is self priming and will deliver approximately 7½ gallons per minute at 100 lbs pressure and 1,750 rpm. Pressure range is from 0 to 200 psi. The pump is furnished with ¾ in. ports; recommended speeds to 1,800 rpm. Weight of this model is 4½ pounds.

Hypro Engineering Inc., 404 No. Washington Ave., Minneapolis 1, Minn.

PUSHNUTS DESIGNED FOR USE ON UNTHREADED ROD, eliminate the need for threading, notching, and cotter pins, yet provide removal resistance of 100 lb or more. Pushnuts are made of spring steel, heat treated and tempered The grip is obtained through nine-point contact on the rod. Three gripping fingers at a circular opening, plus six sharp points of contact on teeth inside the nut, provide the resistance to removal. Available in two types: C type (closed end, or acorn) and K type (open end). C type is available in sizes for 3/16 in. and ¼ in. rod; K type in sizes for 3/16 in., ¼ in. and 5/16 in rod. Palnut Co., 61 Cordier St., Irvington 11, N. J.

CONTINUED ON PAGE 224

CONTINENTAL'S PROOF BOOK

W. N. LARKIN

Amherst College, B.A., 1937. Joined Sargent and Company 1949 as Assistant Superintendent in Lock Division. Became Purchasing Agent 1951. Active member of National Purchasing Agents Association; Executive Associates Forum; Quinnipiack Club; N. H. Country Club.

SARGENT & COMPANY
INCORPORATED 1868
MANUFACTURERS
NEW HAVEN 9, CONNECTICUT

December 15, 1952

Continental Screw Company
New Bedford, Massachusetts

Gentlemen:

This is the time of the year when we take inventory. It has always been my practice to take "inventory" of our suppliers and see how they have shaped up and what kind of a job they have done for and with Sargent & Company over the past 12 months. It is certainly a pleasure to inform you that your performance has been among the best.

It is interesting to note that only a few short years ago you received your first order from us and that was for taped screws. Since that time, because of your performance and quality, you have grown to be one of our major sources for fasteners. When I asked myself why, the answer was clear. You have furnished us with a quality product at a fair price and completely fulfilled your obligation. Whenever we needed a little extra something you went out of your way to take care of our needs.

We sometimes forget that business isn't done primarily by companies but by the people who make up these companies, and your people have certainly made doing business with you a pleasure. It is my sincere hope that this fine relationship will continue to prosper and grow.

Cordially,

SARGENT & COMPANY

W. N. Larkin,
Purchasing Agent

You too can count on Continental ©TM

CONTINENTAL SCREW COMPANY INC. 1904

Manufacturers of HOLTITE Fastenings For Every Purpose

CONTINENTAL SCREW COMPANY, NEW BEDFORD, MASS., U.S.A.

New Model Pulse Generator

The new model B-2 Pulse Generator is an instrument for the generation of pulses of variable width, amplitude, delay, and repetition rate, with accurate control of all factors by means of helical potentiometers.

It has duty factors as high as 25 percent and repetition rates as high as 100 kc. and has an internal oscillator giving rates from 10 cps to 100 dc in four decade ranges. It may be externally triggered, or used in single pulse operation. The main pulse may be delayed from 0 to 10,000 microseconds from the synchronizing pulse in five decade ranges.

The main pulse is variable in width, from 0.2 microsecond to 1,000 microseconds in four decade ranges, and has a rise time of 0.02 microsecond, a fall time of 0.05 to 0.1 microsecond (depending on width), and maximum amplitude of 100 volts into an open circuit. The internal impedance of the main pulse output is 100 ohms.

The amplitude of the outputs is adjusted by a constant impedance 100 ohm step attenuator, having a 60 db range, together with a 10 db fill in attenuator.

Synchronizing pulses are available at: 1.5 microseconds before main sync pulse; main sync pulse; 1.8 microseconds before leading edge of main pulse; at leading edge of main pulse; and, at the trailing edge of main pulse.

Rutherford Electronics Co.,
3707 S. Robertson Blvd., Culver City, Calif.

Synthetic O-Rings For Special Seals

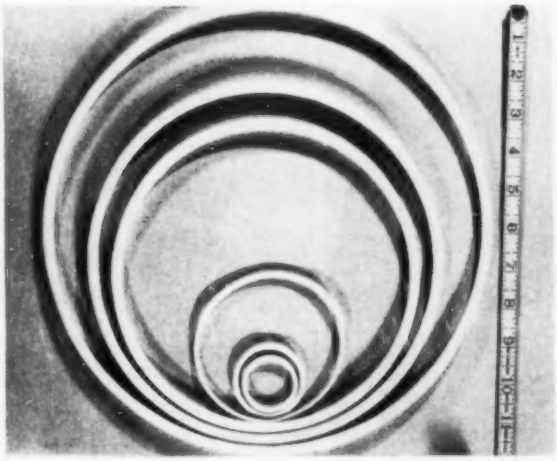
Three series of Kelon-T (Teflon), Kelon-F (Kel-F, fluorothene), Nylon, and Polyethylene O-rings have been developed for special sealing applications where elastomeric (rubber) O-ring compounds are unsatisfactory.

The synthetic O-rings are said to offer desirable properties that have not been possible in ordinary O-rings such as heat resistance, chemical inertness, and low coefficient of friction. The Kelon-F and Kelon-T O-rings are unaffected by oils, acids, bases, or solvents. Useful temperatures range from —110 F to +500 F for Kelon-T O-rings, and 425 F for Kelon-F O-rings.

The new synthetic O-rings will resist new hydraulic fluids and missile propellants now used in power plant and fuel systems of jet engines and guided missiles.

The O-rings are recommended for hydraulic, food processing, chemical, petroleum, pump, valve, aircraft, and missile installations.

Sizes of Kelon-T series ST-2672 O-rings and Kelon-F series SF-2672 correspond to those of AN6227; series ST-2603 and series SF-2603 correspond with AN 6230; and series ST-2609 and SF-2609 correspond with AN 6290.



W. S. Shamban & Co., 5747 Marilyn Ave., Culver City, Calif.

A TERMINAL ADAPTER designated as type 2592, which increases flexibility of connections to cathode-ray oscillographs, permits easier use of coaxial cables for carrying signals to the banana-jack type terminals of cathode-ray oscillographs and other test equipment, and also gives correct impedance-matching termination for the coaxial cables. The adapter may be used on any banana-jack type terminals spaced ¾ in. on centers. Built into the adapters are impedance-matching resistors. Available are 52, 75, and 93 ohm adapters for UHF and BNC coaxial connectors and 52 and 75 ohm adapters for type N coaxial connectors. The resistors are the nearest 5 percent RMA valve to the surge impedance of the cable. Allen B. Du Mont Labs., Inc., 1500 Main Ave., Clifton, N. J.

CONTINUED ON PAGE 226

New MEAD INDUSTRIAL AIR POWER CATALOG ready—

Full of suggestions FOR FASTER, CHEAPER PRODUCTION

New MEAD AIR POWER CATALOG illustrates, describes the complete line of famous MEAD-DESIGNED Air Operated Devices which have been speeding work, saving time and money for America's most "Cost Conscious" plants! Get your copy.

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Midget Air-Clamps* · Single Acting Air-Clamps* · Double Acting Air-Clamps*

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Send free copy of new, colored MEAD INDUSTRIAL AIR POWER CATALOG describing the complete line of famous Mead air-operated devices.

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Electronically Controlled 25 Ton Tester

This 50,000 lb capacity universal testing machine, model FGT, features an electric weighing system, and an electronically-controlled, motor-driven loading mechanism.

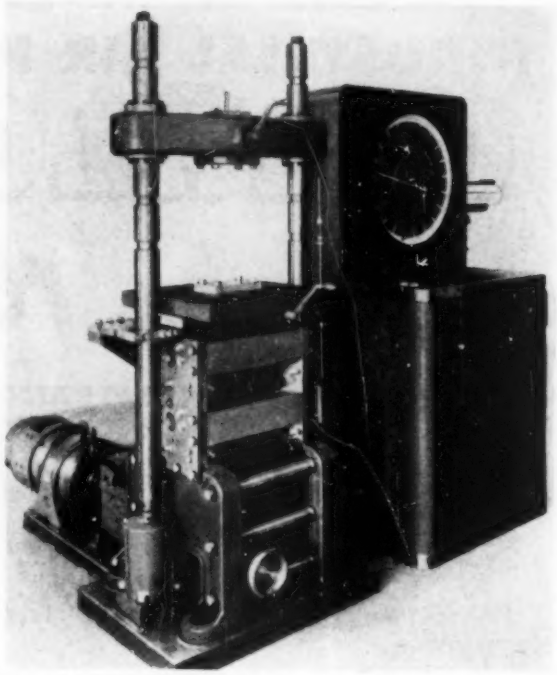
The testing machine loads are measured by means of two SR-4 universal load cells of 30,000 lb. capacity each, at the base of the two vertical tie rods, and resistance wire strain gage instrumentation of the totalizing circuit type which gives instantaneous response.

Three load ranges are provided on a separate indicator with 24 in. dia. dial having 1000 graduations in 66 in.: 0-50,000 lb, 0-10,000 lb, and 0-2000 pounds. Lower ranges are available by fitting a detachable SR-4 universal load cell on the crosshead and connecting it into the load indicating dial.

The load system utilizes a single enclosed reversing screw rotated by a 2 hp. motor under thyratron tube type control over a speed range of 360 to 1. The maximum stroke of the machine is 8 in. The test table is 20-in. square. Maximum vertical space is 24 in. for both tension compression tests. Clearance between columns is 21 in., and the crosshead is adjusted by means of the main motor drive.

Associated stress-strain recording equipment can take signals both from load cells and from an SR-4 type extensometer. For normal rates of recording an SR-4 converter is inserted so that a standard microformer can be used. An X-Y recording potentiometer can also be used. For high straining rates or for alternating loads, oscillographs or oscilloscopes may be used to record load vs. strain, the latter on a persistent screen.

Optional accessories include automatic equipment for printing values of "extension-under-load," offset yield strength, or ultimate strength controlled by electronic devices which trigger the printer.



Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.

Basic Scaler Easy to Operate

A simple, low cost, basic scaler for laboratories in the field of radio-activity, the SC-19 utility Scaler uses an electronic scale of 256, a wide range preset count selection and a high voltage power supply for geiger tubes.

The instrument uses eight electronic scales-of-two, giving a scaling factor of up to 256, followed by a mechanical register. A scale selector switch allows the choice of four scaling factors of 32, 64, 128 and 256. The total number of counts accumulated is obtained by multiplying the register reading by the selected scaling factor and adding the values of the neon interpolating lights.

Predetermined counts ranging from 320 to 256,000 may be selected by means of a preset count switch which will stop the register at 10, 100 or 1,000.

Special connectors make possible the use of a separate clock which is operated by the count-stop-reset switch.

The utility scaler has a resolving time of about 10 microseconds and a maximum counting rate of 1,000 cpm on the register. Counting rates of up to 60,000 cpm result in less than 1 percent coincidence loss. The high voltage power supply is regulated so that 1 percent change in line voltage causes only 0.1 percent change in high voltage.

Tracerlab, Inc., 130 High St., Boston 16, Mass.

—CONTINUED ON PAGE 228

Photo courtesy Tucker Sno-Cat Corporation, Medford, Oregon

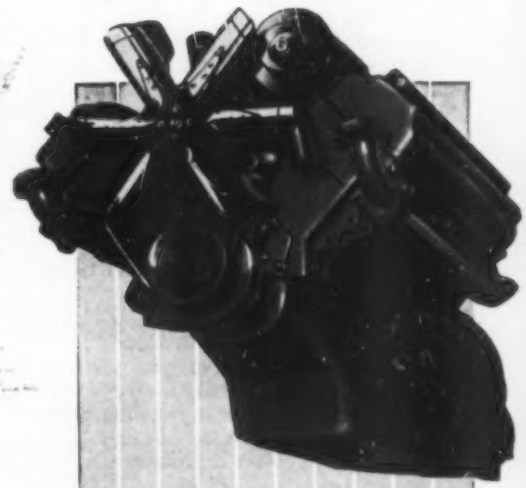
Snow, deep and powdery, on his favorite slope may be cause for rejoicing to the skier. But, to the men who must keep 60,000 volts of electricity crackling through ice-crusted lines in the high Sierras, to the men who must keep the lines of communication and transportation open to the West Coast . . . snow in any form spells possible trouble.

When the going is toughest, mountain men turn to their best friend, the Tucker Sno-Cat. These four-pontoon, full-track vehicles carry men and equipment *over the snow*—in minutes—to trouble spots it might otherwise take days to reach.

The 180 horsepower Model 20 Chrysler V-8 Industrial Engine gives the Sno-Cat extreme power without increase in weight, while Chrysler gyrol Fluid Drive and automatic transmission provide smoother, faster application of power to the double-drive axles. This combination is ideal for uses which require a powerful engine that will not stall under heavy loads and at the same time require an engine and transmission protected against the wear and tear of sudden starts and stops.

For greater power and economy in your equipment, check the two new Chrysler V-8 Industrial Engines as well as the seven six-cylinder models. See your Chrysler Industrial Engine Dealer for detailed information, or write: ***Dept. 41, Industrial Engine Division, Chrysler Corporation, Trenton, Michigan.***

180 horses . . . man's best friend in the wintry high Sierras



CHRYSLER
Industrial Engines
HORSEPOWER WITH A PEDIGREE

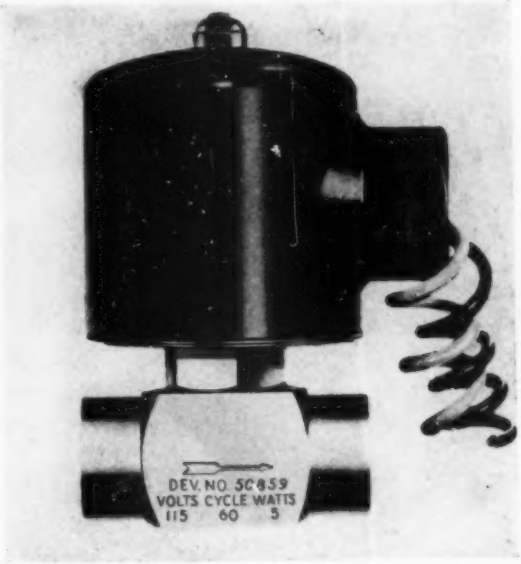
All-Purpose Solenoid Valve

Designed for a wide range of industrial applications, the new model 67 solenoid valve is available in two body styles and with two types of needle and seat construction.

Where positive seal-off is required, the valve has synthetic resilient disk-type needle, seating against a stainless-steel orifice. This assures "bubble-tight" operation under the severe conditions. For other applications, the valve is furnished with a stainless-steel needle, in combination with a strong, corrosion-resistant stainless steel valve seal. The design prevents "ovaling" and wire-drawing of the seat, even after periods of continuous operation.

Available in two body styles, $\frac{3}{8}$ in. female pipe or $\frac{1}{2}$ in. O.D. tube sweat connections, the valve can be used for air, oil, water, gasoline, alcohol, detergents, refrigerants, Butane, propane or other noncorrosive liquids and gases. Capacity on water is 78 gph and on refrigerant applications 1 ton Freon 12. Working pressure is up to 300 psi. Operating differential: liquid lift up to 130 psi, air and gases 250 psi, refrigerants 200 psi.

Operation is said to be quiet, with no hum or vibration. An overpowered coil provides the lift, even at 85 percent of rated voltage. Moisture, and frost-resistant construction gives long performance, and protects against coil burnout.



A-P Controls Corp., 2450 N. 32 St., Milwaukee 45, Wis.

Small Size Gaging Head Measures Irregular Parts

A new type of gaging head known as the Plunjet has been developed for use in conjunction with several makes of air gages for gaging wide tolerance work. Because of its small size, it can be adapted to a wide range of applications and is said to be universal in its use. The gaging head is calibrated by a feeler gage having minimum and maximum limit elements. Two types are available, the normal and the reverse, and they may be had in three standard ranges: 0.040, 0.020, and 0.010. Plunjets for special ranges and closer tolerances can be supplied on special order.

The Plunjet may be used for measuring irregular parts such as the profile of aircraft turbine blades and buckets. At present, eighteen of these gaging heads are used to get a simultaneous measurement at eighteen points of an aircraft turbine blade profile.

It is said to be particularly useful for measuring flatness; for general machine shop work such as height gages, squareness and depth checks; in gaging wide tolerances on inside diameters exceeding 3 in.; and on lathes and other metal removing equipment to tell when the part is reaching the proper size before it is down to the finished dimension.

The Sheffield Corp., Dayton 1, Ohio

Horizontal Center-Break Switches

A line of PMK horizontal center-break switches has been developed with a new contact assembly featuring: independently sprung pressure-applying springs; a new bronze ball-bearing swivel terminal; and insulator bearings with non-rusting, double race, stainless steel ball bearings.

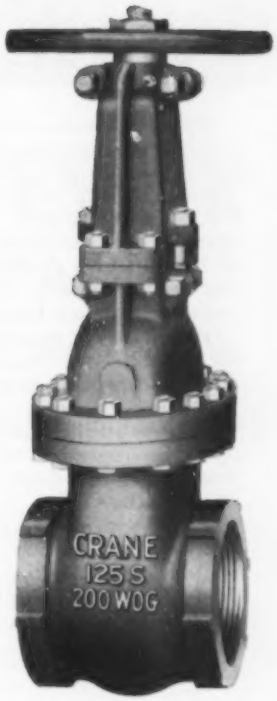
The PMK 22 switch has a direct linkage connection between the two rotating insulators, and has a center bearing with a toggle linkage between the two rotating insulators.

These switches are available in all standard voltage ratings from 7.5 to 161 Kv, and in ampere ratings of 400 (up to 46 Kv) 600 and 1,200 amp for upright and inverted mounting.

Delta-Star Electric Co., 2437 W. Fulton St., Chicago, Ill.

—CONTINUED ON PAGE 230

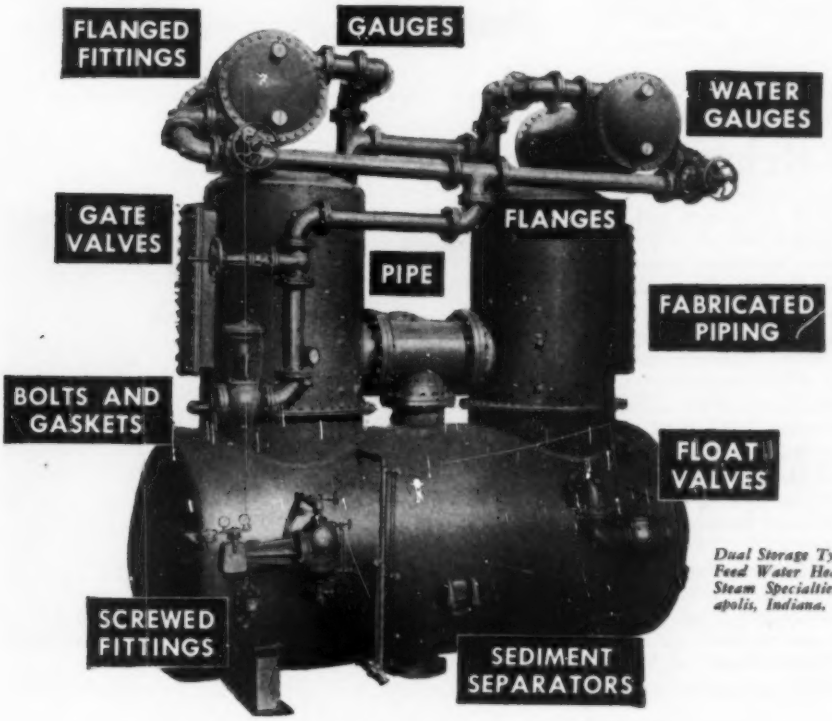
Spend less time on piping specs . . .
See your CRANE Catalog first



Yes, you'll spend less time on piping specs by going first to your Crane Catalog. Here's why: Crane offers the world's most complete selection of quality piping materials . . . there's rarely need to compromise or search elsewhere. Furthermore, with each item, Crane gives complete information including sizes and dimensions, tabulated pressure and temperature ratings, design, material and construction details—plus a run-down of recommended services. In addition, there's a wealth of general engineering data to help with your design problems.

But here's the real advantage to be gained in specifying Crane—your finished product will have an added value that's recognized by machinery buyers. From long experience, they know that "Crane equipped" means equipped for lasting service.

FOR TOP QUALITY EVERY TIME . . .
DEPEND ON THE BROAD CRANE PIPING LINE



Dual Storage Type Deaerating Feed Water Heater by Stickle Steam Specialties Co., Indianapolis, Indiana.

FOR ALL-ROUND SERVICE on steam, water, oil, or gas lines . . . Crane recommends 125-Pound Iron Body Wedge Gate Valves, brass trimmed or all-iron. Available in Non-Rising Stem, O. S. & Y., Underwriters', and Quick Opening patterns. Screwed, flanged, or hub ends. Sizes: 2-inch and larger.

The Complete Crane Line Meets All Your Valve Needs. That's Why—
More Crane Valves Are Used Than Any Other Make!

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

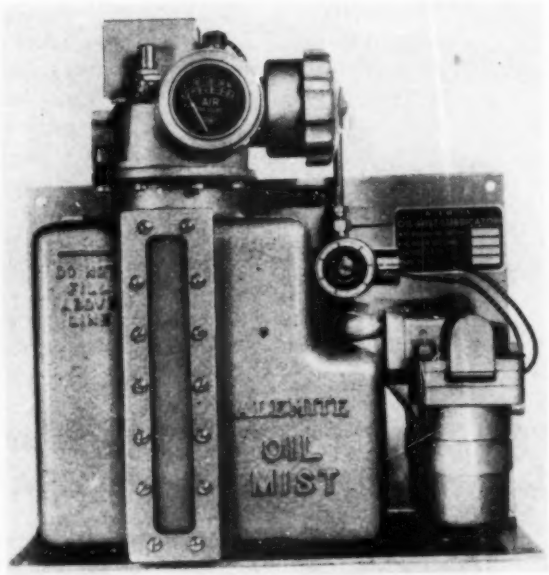
Oil-Mist Lubricators Have Low-Level Cutout

Oil-mist lubricators have been developed with one-gallon oil reservoirs and built-in automatic warning switches which shut off the machine as the oil becomes too low.

Earlier models, using a solenoid switch, gave lubrication when the machine on which they were used was in operation, but had provision only for visual measurement of the oil left in the reservoir. The manufacturers claim that the new models reduce dependence on the human factor in automatic lubrication.

Two models of the oil-mist units with gallon reservoirs are available. One, model 4958, is wired with a normally open switch which makes contact when the level of the oil goes below 23 ounces. The switch sets off an immediate warning by red light and horn. Model 4859, also with a one gallon reservoir, has a closed switch which breaks contact when the oil level goes below 23 ounces and shuts off the machine.

Two new models of oil-mist lubricators with 12-ounce reservoirs having low-level signalling devices are also available. Model 4960 shuts off the machine as the oil level drops, while model 4961 either sets off a warning horn or flashes a red light when oil falls to the two-ounce mark.



Stewart-Warner Corp., Alemite Div., 1826 Diversey Parkway, Chicago 14, Ill.

Sensitive Relay for High Speed Operation

Especially adapted for use with transistors and germanium diodes, a new sensitive relay is hermetically sealed with either air or inert gas, and has a sensitivity running as low as 10 milliwatts. The unit will operate as low as 0.0008 amperes. Contacts are single pole, double throw to 3 amps, 24 volts d-c, 115 volts a-c, non-inductive. Coil resistances are available from 4 to 20,000 ohms. Standard temperature range is —55 C to +85 C. High temperature units may be had to cover range from —65 C to +200 C. Environmental characteristics: vibration 20 G to 60 cycles, 10 G to 200 cycles; shock and acceleration in excess of 50 G.

The unit features high speed operation, operating at 2 to 3 milliseconds, depending somewhat upon coil inductance. Its small size is an additional feature. The relay is 1 in. dia, height, $2\frac{3}{8}$ in., weight, 2.14 oz, (61 grams). It is available as a plug-in or solder hook unit with a variety of mounting brackets.

Designed for use in airborne equipment where space and weight are at a premium, its construction meets regular stresses and strains of flight. Applications also include telemetering, radar and radio, rockets and guided missiles.

Neomatic, Inc., 11632 San Vincente Blvd., Los Angeles 49, Calif.

DESIGNATED MODEL 109, a new electronic wattmeter uses an amplifier to drive the potential coil of dynamometer wattmeter. The input impedance is 500,000 ohms, eliminating errors due to potential coil current. Good sensitivity allows measurement of low-level circuits, or those with only a small test potential. A frequency response of 20 to 3,000 cps permits measurement at all power frequencies and their harmonics, of nonlinear circuits with harmonics, and of low audio frequencies. Ranges of 300, 100, 30, 10, 3, 1, 0.3, 0.1, and 0.03 watts have full-scale accuracy within 2 percent. Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio.

CONTINUED ON PAGE 232

PRODUCTION SPEED
with Laboratory Accuracy

SPRING TESTER

Works on New Principle

Tests any resilient material — including cork, felt, rubber, sponge rubber, springs (for compression, tension, torsion) piston rings, motor mounts, Belleville washers.

Your Choice of Gauges — "GO" or "NO-GO", or Reading Directly in Pounds

New principle cuts hand and eye motion 60%, by eliminating height measurement. Height remains fixed, regardless of load. This reduces operator fatigue and cuts cycles to about TWO SECONDS, with air cylinder type tester, as illustrated.

Hand Operated Types Also Available

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Other Link Products

- ★ Electric Dynamometers, A.C. and D.C.
- ★ Continuous Indicating Lubricating Oil Consumption Scale
- ★ Platform Scales
- ★ Torsion Testing Machines
- ★ Fatigue Testing Machines
- ★ Hydraulic Presses
- ★ Tension Registering and Automatic Control Device

Representatives wanted — write for open territory

LINK ENGINEERING CO.

13843 ELMIRA AVE., DEPT. R 5 · DETROIT 27, MICH.

Sensitive, Accurate Electronic Recorder

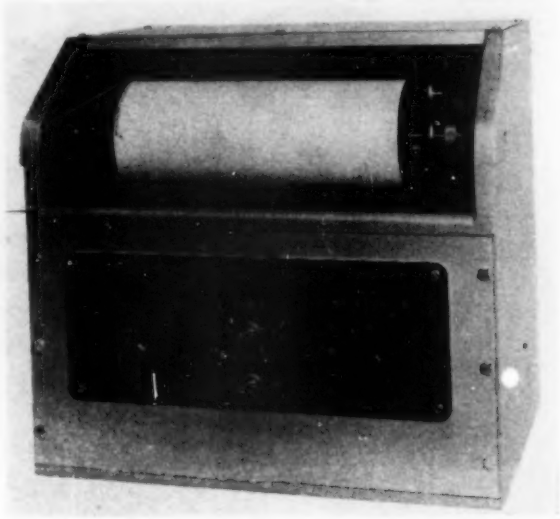
A new model 51 electronic recorder, having the high-speed found in the electronically controlled null balancing system, rotates the recorder chart drum in direct proportion to the strain or deformation of the specimen under test, and produces a stress coordinate by horizontal movement of the pen of the recorder.

The model 51 recorder may be applied to all types of testing machines for tension, compression, and transverse testing. When used with beam and hydraulic gage types of machines an additional electronic null system is necessary to drive the load pen across the chart.

Sensitivity of this instrument is 0.05 percent of full scale for each range; accuracy of strain coordinate is plus or minus 1/5 division (0.2 percent of full scale); accuracy of stress coordinate is equal to that of the testing machine. Standard instrumentation is available for motion detectors for magnifications ranging from 1,000 :1 to 1:1, magnifications are available by flipping a switch, and magnification may be changed without stopping the test.

Drum rotation of the model 51 recorder is 10 inches in 4 sec for full scale. Curves are plotted on letter size (8½ x 11) cross section paper.

Calibration of this instrument is based on factory sealed fixed linear distances. All component parts such as amplifier, motor, or gear backlash, have no effect on calibration.



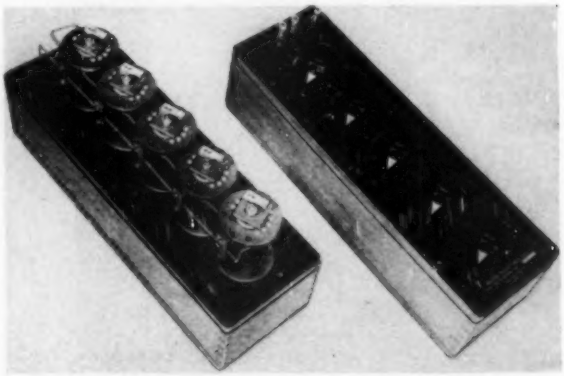
Tinius Olsen Testing Machine Co., 1084 *Easton Rd., Willow Grove, Pa.*

Resistance Boxes Have Variety of Use

Type 750 resistance boxes are complete assemblies of two or more type 275 decade units, mounted on a black panel, and enclosed in a shielded walnut cabinet. The cabinet shielding consists of a full copper lining making electrical contact with the metal panel for complete isolation of the resistive elements. There is no electrical circuit between the shield and resistance elements. Three terminals are provided, two for the resistance circuit and the third as a ground connection to the shield.

The switch forms a short, direct, low resistance path between contact and insulated collector ring. The switch consists of three independent silver alloy U blade brushes having independent spring wiping (off-set) action to give positive contact.

These precision boxes may be used as laboratory standards, as direct reading resistor elements in bridge circuits, as shunt or series elements in transmission networks, or where stable, adjustable resistance elements are applicable.



Daven Co., 191 *Central Ave., Newark, N. J.*

A POLYVINYL RESIN emulsion which remains stable after exposure to freezing temperatures sets at room temperatures, and is suitable for gluing certain types of wood, laminates and other porous and semi-porous materials. Full- strength bonds are developed at any plant temperature from 50 to 110 deg, and remains stable after exposure to freezing temperatures. Borden Co., 350 Madison Ave., New York 17, N. Y.

A SERIES OF FIXED COAXIAL PADS has been developed for application in circuits operating at frequencies from zero to 10,000 mc. Six, 10, and 20 db pads are available, and of conventional Pi and T construction, using metallized film resistors. Their small size and rugged characteristics make them applicable for microwave circuits. Telewave Labs, Inc., 100 Metropolitan Ave., Brooklyn 11, N. Y.

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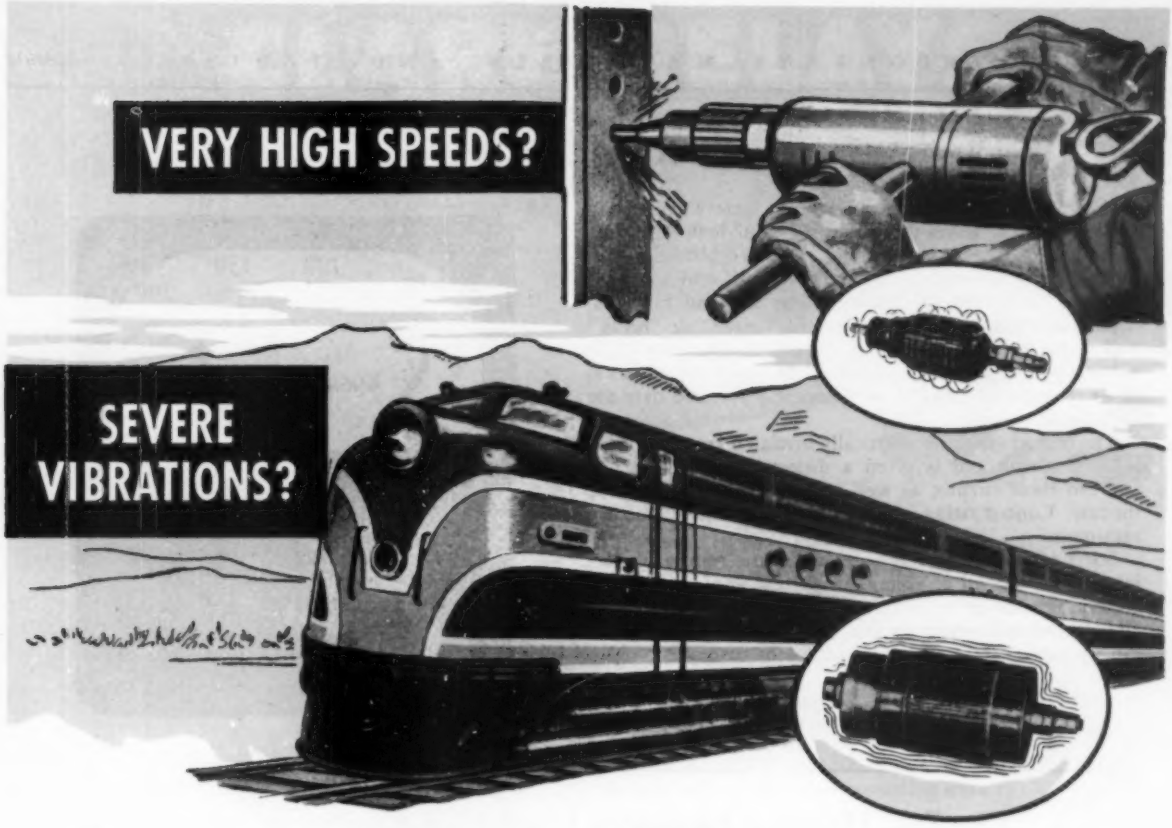

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Company.....
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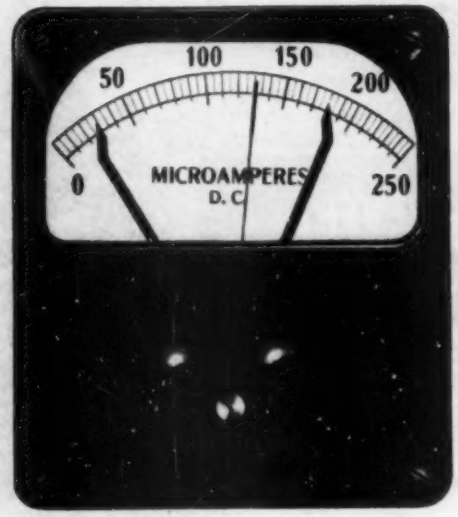
City..... Zone..... State.....

Dual Purpose Contact-Making Instrument

A contact-making instrument of the new core magnet mechanism type, serves the dual function of both indication and control. Known as model 1087, this switchboard instrument has two adjustable stationary contacts, and a contact which is carried on the pointer. The low and high stationary contacts, mounted on indices, "make" or "break" under direct influence of the current in the instrument moving coil. Each index indicates the point of operation of its contacts, and can be independently adjusted over the entire scale range.

The contact circuit is electrically insulated from the moving coil circuit and is given a dielectric test of 500 a-c between these circuits, as well as between all circuits and the case. Contact rating is 6 v, 0.030 amp d-c non-inductive, maximum.

Some of the applications are: automatic testing of vacuum tubes; control of voltage or current levels of standby battery systems or in electroplating processes; indication and control of speed; or any one of the functions that can be expressed in terms of voltage or current.



Weston Electrical Instrument Corp.,
617 Frelinghuysen Ave., Newark 5, N. J.

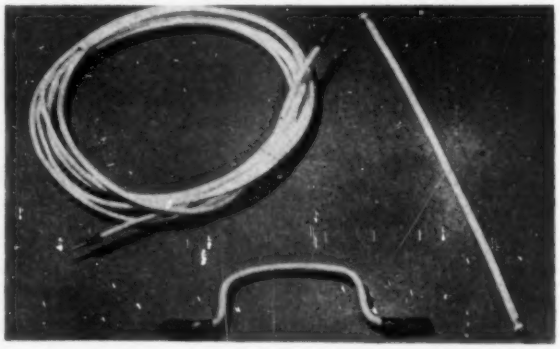
Flexible Heating Elements Used as Resistors

While these flexible heating elements were designed primarily to give wide dispersion of low thermal output, in areas where heaters would be crowded and heat localized, the manufacturer states that they may be used as resistors or heat transmitters.

Available in lengths from 2 in. overall to 20 ft overall, diameters run from 0.108 in. to 0.190 in. over their insulated surfaces, depending on degree of dielectric constant required, or watts output per linear inch. Tinned terminals $\frac{1}{16}$ in. dia by desired length, or with lug type terminals as shown are also available.

The elements operate in ambient temperatures from —65 to 250 F. Maximum sheath temperature is held to 375 F by regulation of wattage-load requirements of the application. The manufacturer states that continuous operation at temperatures below these maxima are advisable for extended life expectancy.

The units will withstand vibration test of 20 Gs, and can be furnished with fungus proof insulation. Resistors are of nonferrous round resistance wire helically wound on ferrous-free asbestos or fiberglass cord. They are insulated with a single wall fibreglass sleeve for normal dielectric test requirements of 500 v prescribed for certain military requirements, and are also insulated with double-wall fibreglass sleeve for tests to 1,000 volts. Also available with colored insulation in black, natural, yellow and red.



Acra Industrial Electric Co.,
9901 Pacific Ave., Franklin Park, Ill.

Simulation of Functions For Computers

Computations involving backlash, dead-zone, and limit-stops may be accurately made on any real-time analog computer such as IDA, REAC, or GEDA, by a new unit, designated model NLU-2.

The NLU-2 has two completely independent channels, each of which may be set for any of the three modes of operation. Variables of any magnitude normally encountered in commercial computers may be used as inputs, while complete front-panel adjustment of the function to be generated is accomplished. The unit measures 14 x 8 x 8 inches.

Computer Corp. of America,
149 Church St., New York 7, N. Y.

—CONTINUED ON PAGE 236

CLARE RELAYS

Section of the Reservisor's* "brain" showing vacuum tubes and relays mounted in sub-assemblies for easy maintenance.

IMMEDIATE INFORMATION on reservations for American Airlines' 1000 flights a day is available to airline personnel through the use of The Teleregister Corporation's Magnetronic Reservisor,* the first completely automatic reservations system.

With its 1500 tubes and 1400 CLARE relays, the Reservisor* is also a high-speed computer, a storage and filing system, data transmission system, display device, and a logging or recording unit.

In their vast experience with electrical controls, Teleregister's engineers have acquired a knowledge of relays that is wide and deep. The importance which they attached to selecting the best possible relays for the Magnetronic Reservisor* stands out in these their own words, "Choice of components, equipment layout, and circuitry were aimed at reliability. First of all, the incidence of trouble should be held to the minimum. This has been accomplished by using only the finest components and by using a sturdy relay instead of a vacuum tube wherever possible." Their deliberate choice of CLARE relays is therefore charged with meaning for industrial designers.

CLARE sales engineers are located in principal cities to cooperate in the development or "custom-building" of relays to meet your most difficult design applications. Call them or write: C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable address: CLARELAY.

Clare Type J Relay of which 1400 are used in Magnetronic Reservisor* is an extremely compact and lightweight relay.

*Trade Mark of The Teleregister Corp.

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Starting with TEFLON*, United States Gasket Company engineers have developed a series of "Filled" Fluorocarbon materials, greatly broadening the scope of usefulness of this wonder-plastic. For example, United States Gasket Company "Application Engineering" has already helped solve such material problems as long-wearing chemical resistant bearings and pump impellers; valve and pump packings, expansion joints and chambers, gaskets; the metal plating of Teflon; the hermetic sealing of electronic components; soldering and cementing to Teflon; etc., etc.

If you have a special materials problem, that one of these Teflon "alloys" might solve, tell us about it. Our engineering department will work with yours to determine the Chemelec Mixture best suited to your requirements.

UNITED STATES GASKET COMPANY

FLUOROCARBON PRODUCTS DIVISION

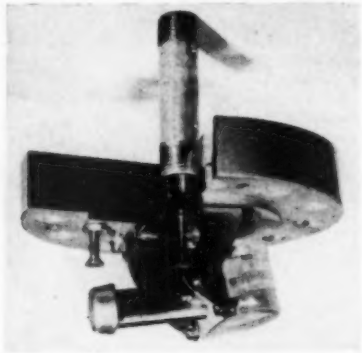
FABRICATORS OF "TEFLON" "KEL-F" AND OTHER FLUOROCARBON PLASTICS

CAMDEN 1, NEW JERSEY

*duPont's trademark for its tetrafluoroethylene resin.

High Pressure Vent Valve

A high pressure vent valve that operates by means of a counter balanced float of solid plexiglas, is used in the petroleum industry to relieve gas or vapor pockets fromed in pumps. The difference in buoyancy between the float and the counterweight operates a



needle valve which permits the gas to escape through a 0.016 in. dia orifice maintaining a fluid level within the valve case.

All of the principle parts of the valve are of stainless steel except the float which is plexiglas, the counterweight (lead), and the stem guide which is steel. The stem and seat are hardened. The case is cast steel, and the working pressure is 600 to 1,800 psi.

Van Loo Pump & Machine Works, 4868 N.E. Union Ave., Portland 11, Ore.

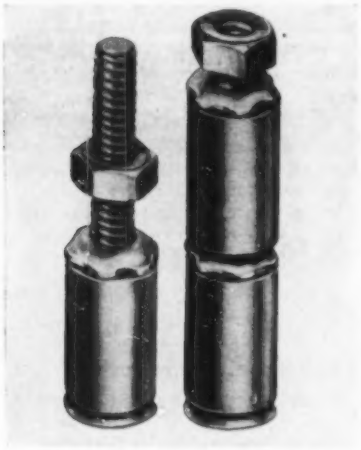
Single and Double Anchor Bolt Assemblies

Recently developed single and double anchor bolt assemblies are guaranteed by the manufacturers to give 50 percent greater anchorage, and to have wide usage, since they can be used wherever anchor bolts or expansion bolts are used.

The anchor bolt assemblies can be easily installed. After insertion of the anchor bolt, lead sleeve and of a new cup-shaped steel anchor, a tamping tool mushrooms the lead first. Several blows will flatten out the steel anchor, driving its ribbed edges into the walls of the hole. Steel reinforces the lead and makes a permanent, solid anchorage that prevents the bolts from loosening.

Another feature of the assembly is that the anchor can be put in masonry, brick, or wood at any angle, and the bolt can then be bent or off-set without disturbing the anchorage.

The single anchor bolts are designed



for general anchorages, with double anchor bolt assemblies used for places where greater anchorage is required. Single or double anchor bolt assemblies can be obtained in bolt sizes from $\frac{3}{16}$ in. to $\frac{1}{2}$ in. and up to 5 in. long.

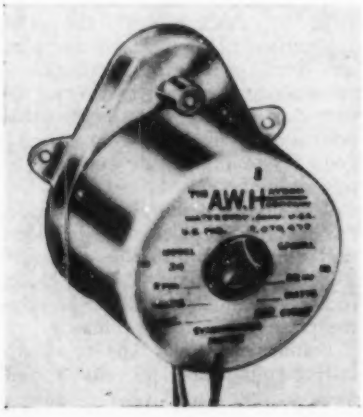
Super-Grip Anchor Bolt Co., 3333 No. 22 St., Philadelphia 40, Pa.

Light Weight, 400 Cycle Timing Motor

A practical 400 cycle synchronous a-c timing motor, for use where light weight and accuracy are required, features almost instantaneous starting and stopping. The use of a single pole throw switch accomplishes effective reversing. One winding 90 deg out of phase assures rapid starting, smooth operating, and ease of reversal.

The dimensions of the 400 cycle motors approximately equal those of the 60 cycle a-c and d-c motors, made by this company, and mounting dimensions are identical, providing interchangeability in all timers. Weight is 8 ounces.

The timing motor operates on 115 v ±10 percent with frequency of 400



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✓ check the analysis
✓ check the performance

and you'll specify

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check the performance—TUF-STUF alloys are light and strong—about 8% lighter than cast bronze and almost as strong as steel. They have a low coefficient of friction as well as good bearing and mechanical properties. They not only retain these properties but resist oxidation at the high speeds and high temperatures of modern production equipment. They will withstand strong acid attack or the effects of brackish waters and are highly resistant to corrosion.

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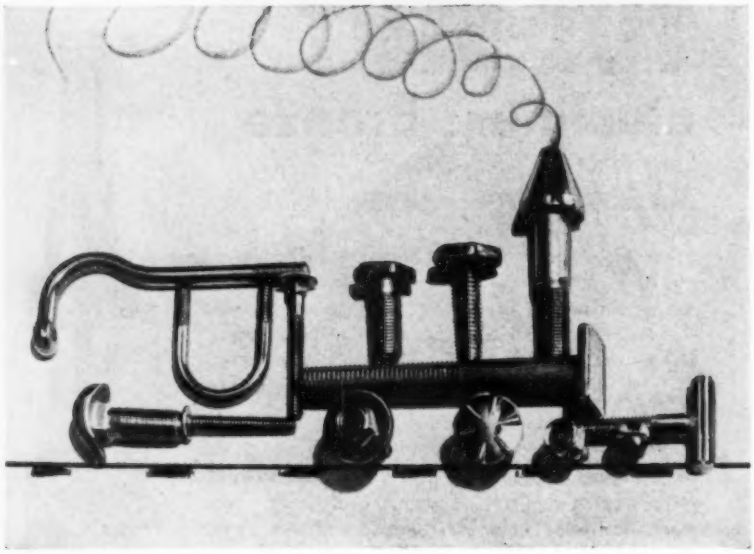

● Take a tip from leading concerns which have found the answer to their fastener problems in specially designed Circle Ⓑ bolts. They are producing better designed, stronger products, with more sales appeal, faster . . . and getting them often at considerable savings in time and money.

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cps ±20 percent. The torque is 0.025 oz-in. at 3,000 rpm starting and running. The motor operates with a power input of 6 watts, including the phase shift network (4.5 watts motor winding). The rotor speed is 3,000 rpm at 400 cps with output speeds available from 3,000 rpm to $1\frac{3}{4}$ rph. The motor meets the temperature, altitude and vibrations requirements of MIL-E-5272.

A. W. Haydon Co., Waterbury, Conn.

High Speed Universal Transmission Dynamometer

A new universal transmission dynamometer consists of a set of gears arranged either as a speed reducer, or a speed increaser with a case mounted in trunion bearings, so as to permit it to rock freely and allow the torque on the casing to be measured through an arm or a scale beam. In this way the dynamometer does not, itself, absorb any load, it merely records the power which is transmitted through the unit.

The dynamometers all have precision gears and oiling system for circulating oil to the gear box. They are made for horsepowers up to 2,000 in high speeds, with top speed being in the range up to 3,600 to 40,000 rpm. A line of small units of this type for low horsepowers, and much lower speeds, is available.

These units have a differential assembly, and can be furnished in ratios of from 3:1 up to 80:1, the high ratios being covered by single stage heliocentric gears.

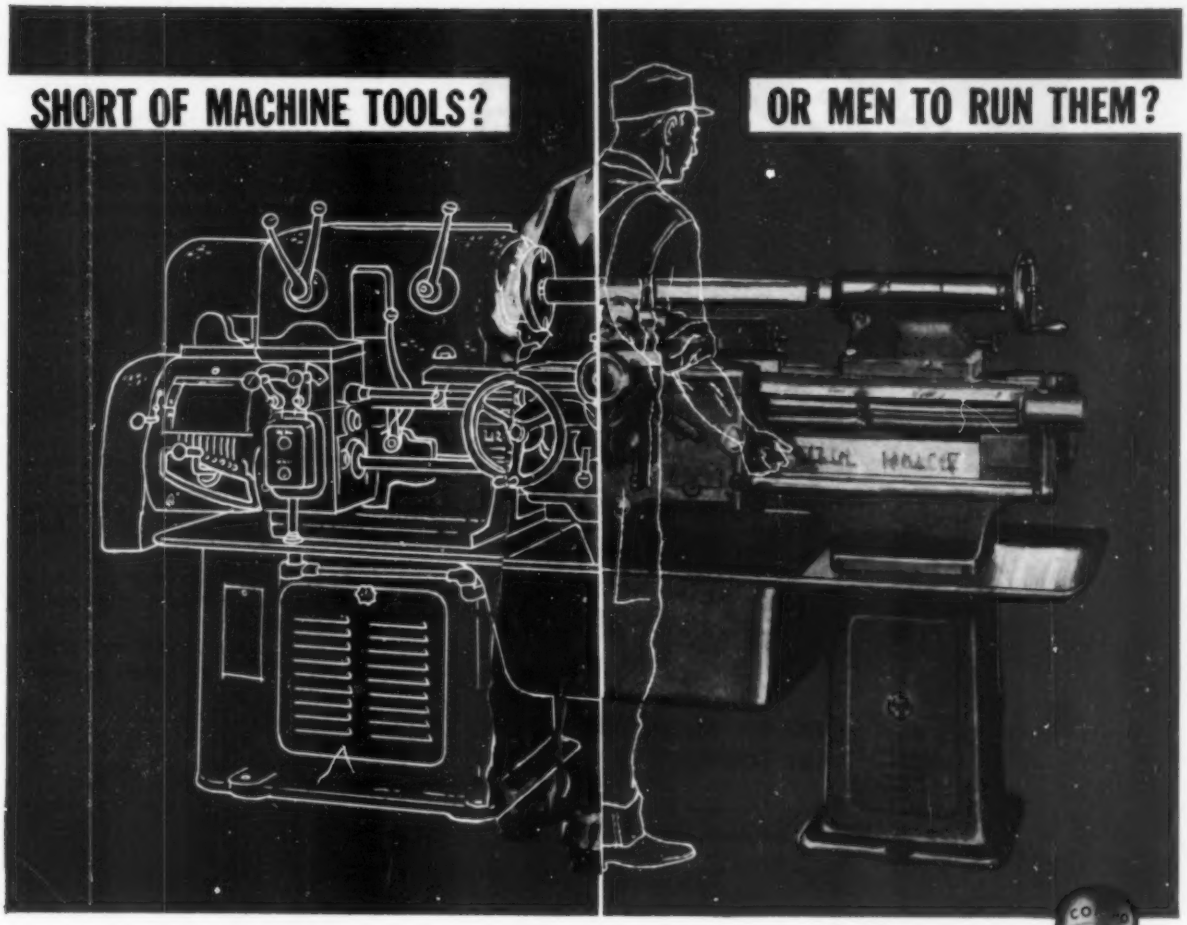
Universal Gear Corp., 19th & Martindale Ave., Indianapolis 7, Ind.

End-Window Geiger Tube

The TGC-8, a stainless steel, end-window geiger tube, designed especially for medical work and other applications where the rapid and accurate counting of gamma radiation is essential, has an end-on efficiency approximately six times greater than normal mica end-window tubes, and is good for counting such gamma emitters as Iodine-131.

This tube has multiple baffles inside the heavy metal sleeve, and has identical dimensions with this company's TGC-1 and 2 tubes, $3\frac{5}{8}$ in. by $1\frac{1}{2}$ inches. It is interchangeable with other equipment made by this company.

Features of the new tube include operating voltage of 1100 volts; a minimum plateau length of 150 volts; a



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plateau slope of approximately 2 percent per 100 volts; and a useful life of greater than 1 x 10^8 counts.

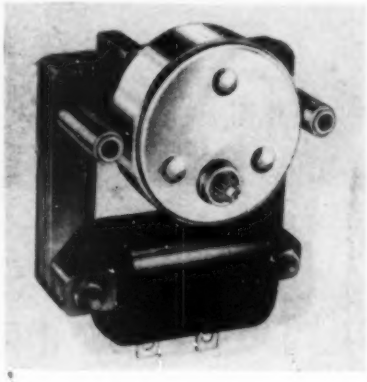
The fill gas used in the tube is helium with an organic quench and the tube has a recovery time of approximately 200 microseconds. It has a standard 4-pin radio tube base.

Tracer Lab, Inc., 130 High St., Boston 10. Mass.

High Torque Motor For Appliance Timing

The model *H*-10 has unique high-torque characteristics that make it of special interest to manufacturers of timers for use in the appliance field. Most prominent examples where automatic time cycling is required are automatic washing machines, dishwashers, and clothes driers.

Claimed to have high torque rating for intermittent load peaks of short



duration, it is compact motor for its torque rating. It has a terminal speed of 3.6 rpm with a peak torque rating of 0.375 lb—inches. Dimensions are $2\frac{3}{16}$ x $2\frac{9}{16}$ x $1\frac{5}{16}$ inch.

The *H*-10 motor also incorporates continuous lubrication, sealed gear train, light-weight rotors, and air-cooled coil.

Telechron, Ashland, Mass.

Precision Toggle Switches

Precision toggle switch assemblies of a new type for multiple circuit control provides a means of switching eight single-pole, double-throw circuits with a single toggle lever.

Built primarily to meet the vibration resistant requirements of aircraft, the assemblies may also be used in any

PROSPERITY in the USA: Who Has It?

How prosperous *are* the people of the United States?

The previous editorial in this series answered this question for the average American. His prosperity has increased only slightly in recent years.

But the average tells only a part, and in many ways not the most important part of the story. Which individuals and groups have prospered more, which less? (The average, the result of a statistical calculation rather than a creation of flesh and blood, tells nothing about that.)

The purpose of this message is solely to get at the facts on this question of how prosperity is distributed. This is not easy. In spite of the crucial importance of the subject, the available information is limited. Even so it is possible to provide a rough answer to the question, "Who has the prosperity?"

We Have Had a Revolution

The distribution of income in the United States has changed so greatly in the past twenty years that Arthur F. Burns, Research Director of the National Bureau of Economic Research, world renowned for its impartiality and technical competence, calls it "one of the great social revolutions of history." A part of this revolution is portrayed by the following table which shows that individual incomes are both much larger and much more evenly distributed than they were twenty years ago. Clearly, a large new middle-class has been created.

DISTRIBUTION OF REAL INCOME

Dollars of Income*	Per Cent of Families in Each Income Group	
	1929	*1951*
Under 1,000	17%	13%
1,000 – 2,000	24	15
2,000 – 3,000	24	18
3,000 – 4,000	14	18
4,000 – 5,000	6	15
5,000 – 7,500	9	14
7,500 and over	6	7
	100%	100%

*Adjusted for price changes to give the dollar its 1951 purchasing power.

Some light on why this income revolution has taken place can be found by tracing incomes to their source. Since 1929, for instance, employees have clearly made the biggest gains in total income. This can be seen in the next table. People who own their own businesses have done second best. Farmers, who are often thought to be doing handsomely indeed, have been outstripped in the income race by employees and businessmen. People whose incomes depend upon pensions, insurance policies, and other relatively fixed returns such as rent, interest and dividends have lagged far behind.

HOW REAL INCOME HAS CHANGED*

Types of Income	Percentage Change 1929 to 1951
Wages & salaries of employees.	+123%
Income of professional men & unincorporated business	+108
Farm operators' income	+56
Rental income	+1
Dividends	+2
Interest	−35

*In this and the previous table account is taken of changes in the cost of living. But adjustment for the changing tax load was not possible, as it is in the computations which follow.

The Biggest Gains

Employees have made the biggest gains in income, but the term "employees" covers a wide assortment of people—from the presidents of the biggest corporations to factory sweepers. How have different groups of employees prospered? Some indication is provided by results of a survey of salaries in 41 corporations made by Arch Patton of McKinsey and Company and recently summarized in the *Harvard Business Review*. This survey showed that between 1939 and 1950, after adjustment both for higher living costs and for higher taxes, factory and office employees made modest gains in income while management personnel suffered losses ranging from 40% to 60%.

While factory and office workers generally have made greater income gains than others, their gains have varied greatly from industry to industry. During the past five years, for example, steel workers' take-home pay (adjusted for both taxes and price changes) has increased by 22%, that of textile workers 9%, employees of general merchandise stores 4%, and that of laundry workers not at all.

What About Organization?

How have organized workers fared compared to unorganized workers? There is no round-up of facts that makes possible a direct comparison between the two. Such evidence as there is shows it is indeed an open question whether union members have done any better than others. Steel workers, for instance, who are strongly unionized are among the highly paid manufacturing workers. Farm workers are generally not unionized, and they work in one of the most competitive industries in America.

But farm workers have made income gains which far surpass those of steel workers. Real wages of farm workers increased 2½ times more than those in the steel industry between 1939 and 1952. This fact may prove nothing more than that, in a period of inflation and manpower shortage, the less skilled workers whose incomes are ordinarily low make the biggest percentage gain in income. Further support for this conclusion is found in the construction industry where real wages of unskilled labor increased 37% between 1939 and 1952, while those of skilled labor increased only 4%.

Why Most Incomes Are Higher

Prosperity, who has it? We may conclude that workers have been getting much more of it lately than managers or property owners, that unskilled wage and salary earners have made the largest gains, and that income generally is much more evenly distributed.

Where has the money come from to raise low bracket incomes? It has come partly from an increase in the total national income, but partly also from cutting down the share received by people in the highest income brackets. While the top 5% received 33.5% of the income after taxes in 1929, their share of income has now been cut about in half. For every $11 of increase in income to the lower 95% of income receivers, about $7 has come from increased production, and about $4 by taking that amount from the top 5%.

Top bracket incomes have now been cut so deeply that the possibilities of increasing the income of the rest of the people by "soaking the rich" have largely disappeared. Indeed, if all of the income after taxes of everyone earning over $25,000 in 1951 was taken away and redistributed among the remaining Americans, each person would receive only about $65.

The significance of this revolution in income distribution is clear. It is that there is only one way by which the great mass of us Americans can continue to increase our individual prosperity. This is by earning the increase through more and more efficient production. In plotting the economic course of the U.S.A. this fact is of decisive consequence.

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NEW CATALOGS AND BULLETINS

A Reader Service To Help Keep You Up-to-Date

(1) ELECTRICAL INSULATING RESINS — Minnesota Mining and Mfg. Co. Booklet, 8 pp. Describes a new technique of embedding electrical components in insulating resins. Applications for hot and cold pouring resins are discussed, as well as the use of fillers to get special characteristics. Illustrations and technical data are included.

(2) MOTOR CONTROLS—Arrow-Hart & Hegeman Electric Co. Catalog 11, 190 pp. Complete information on type RA motor controls, consisting of magnetic starters, magnetic contactors, and reversing contactors. Also data on a line of manual starters, push button stations, and interchangeable control units, midget relays, limit switches, and push button selector switches.

(3) FLEXIBLE COUPLINGS — Thomas Flexible Coupling Co. Catalog 51, 78 pp. Describes a full line of all metal flexible couplings for power transmission. Sections are divided into: light load couplings; couplings for motor and turbine drives; couplings for engine and motor drives; single type couplings for angular misalignment; floating shaft coupling; and special couplings. Covers wide range of horsepower and speeds.

(4) BRONZE BEARINGS—The Bunting Brass & Bronze Co. Catalog 52, 74 pp. Divided into sections on standard stock bearings; bars; electric motor bearings; and engineering data. There are 854 different sizes of standard stock bearings listed from 3/16 to 4¼ in. I.D. with a range of outside diameters available. Also, 324 different electric motor bearings are listed.

(5) INVESTMENT CASTINGS—Precision Metalsmiths, Inc. Booklet, 12 pp. Describes the range of possible uses for investment castings and the facilities available. Step-by-step illustrations show the process of casting ferrous and non-ferrous alloys for parts ranging in weight from a fraction of an ounce to more than 5 pounds.

(6) HIGH PRESSURE TRIPLEX PUMPS —American-Marsh Pumps, Inc. Bulletin 22-295, 6 pp. Contains dimensions, capacities, cutaway drawings on pumps from 300 to 5,000 psi, or 1.1 to 16.5 gpm. Direct drive, and back-geared models are described for such uses as high pressure testing, high pressure boiler feeding, die casting, or pressure molding operations, and others.

(7) COOLANT PUMPS—The Ruthman Machinery Co. Catalog. Indexed as to the types of coolant pumps available, it also has detailed drawings and specifications of each model. Also included is information on motors available for special or unusual requirements.

(8) LOCKNUTS—Industrial Fasteners Institute. Booklet, 24 pp. Includes an illustration, a description, and a short explanation of the principle of operation of 38 representative types of locknuts. As a guide, it assists users in selecting the locknut best suited for each application. Information includes: description, principle of operation, names of manufacturers, and an illustration.

(9) ELECTRICAL COMPUTER—Consolidated Engineering Corp. Bulletin CEC-1802A. 4 pp. Describes a computer for the solution of as many as 12 simultaneous linear equations. Lists applications, and accuracy and time of the solution of various equations.

(10) PLASTIC COATINGS—The Ric-Wil Coating & Mfg. Corp. Bulletins, 8 pp. Two bulletins describe types 1060 and 7100 resin coatings to protect against corrosive conditions. Type 1060 is of the baking or heat-hardening type when baked at from 350 to 400 F. Type 7100 is of the cold-setting type cured at 60-80 F.

(11) AIR CYLINDERS—Miller Motor Co. Bulletin A-105G, 8 pp. Gives complete engineering, design, construction and mounting data including all mounting drawings and dimensions tables covering 13 mounting styles in 1½ in. through 14 in. bores. Covers cushioned and non-cushioned cylinders, single and double acting, single and double rod end, spring return and oversized rod cylinders.

(12) SPROCKET WHEELS — Link-Belt Co. Booklet 2467, 8 pp. Lists 207 sizes of sprocket wheels carried for 78 types and sizes of chains using cast tooth sprocket wheels: class 400 pintle; class SS bushed roller; class H pintle; class C combination chain; and Ewart Link-Belt.

(13) TESTING LAB — Inland Testing Laboratories. Booklet, 24 pp. Describes and illustrates facilities that include: climatic chamber; high and low temperature chambers; vibration test stands; salt spray, and sand and dust tester. Also equipment for tests on: explosion; acceleration, shock, high potential insulation.

(14) SPEED REDUCERS — Dodge Mfg. Corp. Bulletin A-614-A, 20 pp. Engineering information and selection data on the complete line of torque-arm speed reducers, and the overload release, designed for use with the reducer. Capacity range increased to 43 hp, with a speed range from 12 to 320 rpm.

(15) HIGH TEMPERATURE CAPACITORS—Aerovox Corp. Bulletin HTMP 352. Discusses the higher temperatures (—55 to +125 C) and applications of Aerolene-impregnated metallized-paper capacitors. Also lists other types with drawings and dimensions, and performance characteristics such as: temperature range, insultation resistance, power factor, humidity resistance, and life test.

(16) PUSH-PULL CONTROLS — Simmonds Aerocessories, Inc. Booklet AD-311, 12 pp. Illustrated with photos and drawings, the booklet covers construction features, types of installations, design details, principal components, and layout planning on precision push-pull control. Information is given for light and standard duty units in rigid or flexible housings.

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330 West 42nd Street
New York 36, N. Y.

(17) **BALL & ROLLER BEARINGS**—The Gwilliam Co. Catalog 28, 16 pp. Describes a line of ball thrust bearings, step bearings, journal roller bearings, industrial roller bearings, and special bearings. Has large cross-section drawings of each type, together with specifications.

(18) **MOTOR SPEED CONTROLS**—General Radio Co. Booklet 792-A, 5 pp. Discusses the models of Variac motor speed controls for motors: 1/15 hp and less; ⅛ and ⅙ hp; and ¼ and ⅓ hp. Speed torques are given for each type, along with wiring diagrams, specifications, and illustrations.

(19) **ELECTROLYTIC CAPACITORS**—Illinois Condenser Co. Catalog, 15 pp. This catalog contains a listing of every type of electrolytic capacitor used in the electronics, electrical, and allied industries. Included are photos, dimensional drawings, standard terminal codes, and other data.

(20) **CENTER BREAK SWITCHES**—Delta-Star Electric Co. Booklet 5205. Included are drawings, photographs, diagrams, and tables on a type of switch for upright and inverted mounting. The switches have high pressure contacts featuring independently sprung contact shoes.

(21) **POLYPHASE INDUCTION MOTORS**—The Electric Products Co. Bulletin 37-200, 6 pp. Describes large wound-rotor and squirrell cage polyphase induction motors. Illustrations show the special designs of the high-horsepower motors.

(22) **UNIFIED THREAD MANUAL**—Besly-Welles Corp. Includes latest information on taps of British-American unified threads. Also contains data on tap drill sizes, selection of taps for various classes of work and kinds of material, feeds, speeds, how to sharpen taps, types of coolants and screwthread terms and definitions.

(23) **THERMOSTATIC BOOKLET BI-METAL**—W. M. Chace Co., 32 pages. Entitled "Successful Applications of Thermostatic Bi-Metal," it has a summary on thermostatic bi-metal and contains 18 uses of bi-metal as an actuating element in temperature responsive devices, and condensed engineering data for bi-metal element design and selection. It is illustrated with various types of thermostatic devices.

(24) **MATERIALS PUMPS**—Lincoln Engineering Co., Catalog 40. Presents a complete line of air motor operated pumps and accessories for automatic dispensing and application of heavy to light materials such as sealers, adhesives, roofing, waterproofing, and insulating and caulking compounds. Shows 11 standard models for spray gun, pole gun, and flo-gun applications. Also component units for assembling custom design systems.

(25) **ALUMINUM FASTENINGS** — The H. M. Harper Co., Catalog. An expansion in the range of aluminum fastenings has been broadened to include sizes and types of bolts, screws, self-tapping screws, nuts, washers, rivets and accessories to meet almost any need. Complete catalog listing of all aluminum fastenings carried.

(26) **MAGNESIUM FINISHING** — The Dow Chemical Co., Manual, 128 pages. Describes in detail: surface stability, and surface treatment, including cleaning, mechanical finishing, chemical treatments, electroplating, painting, and assembly protection for magnesium alloy die castings, sand and permanent mold castings, and sheet plate and extrusions.

(27) **CARBON GRAPHITE PARTS**—Pure Carbon Co., Inc., Bulletin 52, 32 pages. Includes complete technical data on properties, description of grades, methods of attachments, table of average characteristics and chart of expansion of various metals, as compared to purebon carbon materials. Describes the use of materials for bearings and seal rings and for turbine shaft packing rings, pistons and piston rings, pump and compressor blades, valve seats, meter pistons and half balls, and trolley wheels and shoes.

(28) **TEST STANDS**—U. S. Electrical Motors, Inc., Booklet 1749, 8 pages. Tells how test stands with variable speed can be used in testing magnetos, generators, alternators, hydraulic pumps, constant speed drives and actuators. Test stands ranging in rating from ⅛ to 70 hp. have output speeds up to 15,000 rpm. Dual heads are shown which enable a tester to test two components simultaneously. Graphs show comparisons of variable speed systems, low ratings and relative speeds.

(29) **ELECTRONIC FLOW METER**—Minneapolis-Honeywell Regulator Co., Data Sheet 10.3-5, four pages. Describes a flow meter for the measurement of fluids over a wide range of temperatures and pressures with an accuracy of ½ percent. The system is easily installed and can be used to measure, record and control flow at one or more points.

(30) **ELECTRICAL INSULATING VARNISHES**—Insulation Manufacturers Corp., Catalog, 20 pages. Gives helpful information on varnish selection and use, plus varnish composition, types, functions, colors, processing and care. Data on solvents is also included, as well as detailed description of electrical insulating varnishes for all types of applications.

(31) **LUBRICATION FITTINGS**—Alemite Division, Booklet 22-188, eight pages. Has information on a complete line of lubrication fittings to meet military establishment specifications MIL-F-3541. Has illustration and engineering drawings of all models, plus a cross-reference chart, giving current and former government fitting specification numbers.

(32) **DISTRIBUTION APPARATUS DIGEST** — Westinghouse Electric Corp., Catalog 50-000, 100 pages. Presents complete data on the following distribution apparatus: distribution transformers, dry type transformers, feeder voltage regulators, instrument transformers, meters, instruments, capacitors, reclosers, sectionalizers, and oil switches, oil circuit breakers, air circuit breakers, disconnect switches, porcelain insulators, and delon power fuses. Preceding the catalog section are conversion tables and formulas, and a discussion of standardized sub-stations for distribution systems.

(33) **RESISTORS** — Ward Leonard Electric Co., Catalog 15, 64 pages. Listed are seven distinct stock-type resistors, and a variety of made-to-order types. Ratings range from 50 to 550 watts, while resistance values listed are from 0.04 ohm to 1.75 megohms. Full details on terminals, mountings and enclosures are also given, as well as selection and application data with detail charts and data tables.

(34) **HYDRAULIC POSITIONING**—Farris Hydrotorque Corp., Bulletin 157, 12 pages. An instrument of positioning control, this single-tube system is independent of outside energy. There is no sponginess, and the operator has the feel of direct linkage with positioning accuracies within a thousandth of an inch. Cross-sectional drawings show the parts of the hydrotorque transmitter and receives with specifications given along with thrust and torque capacities of the hydrotorque units.

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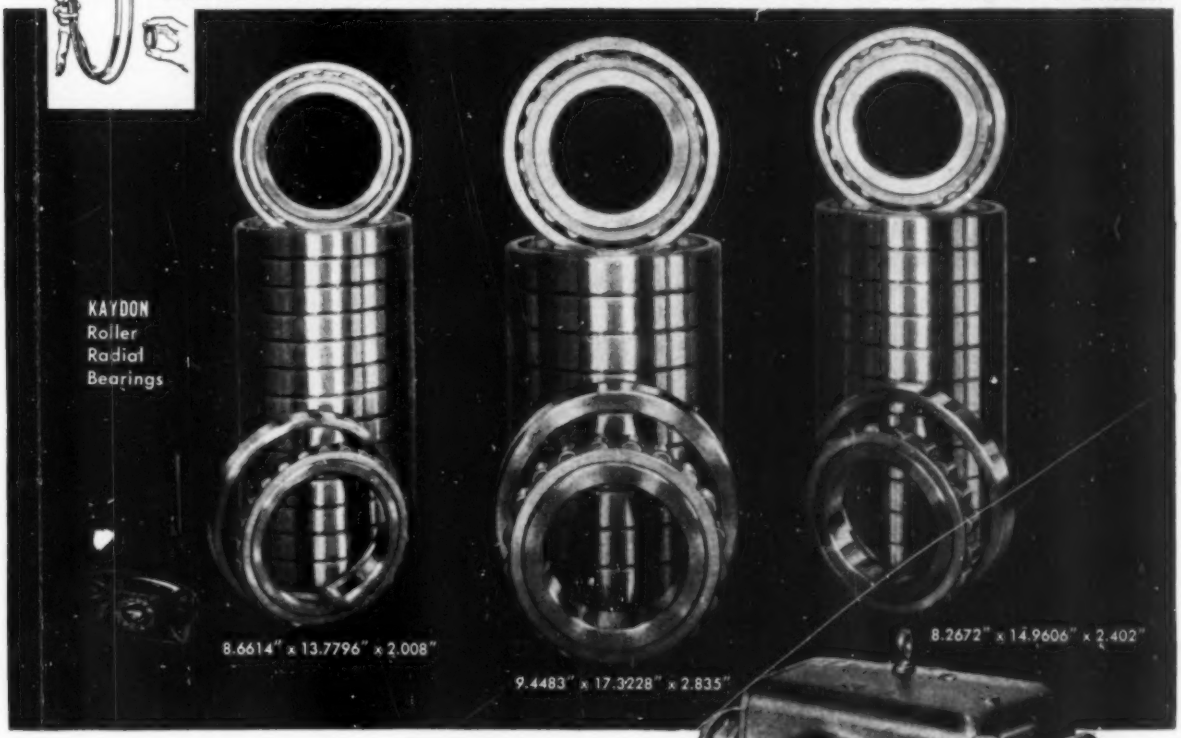
FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



KAYDON and OILGEAR
cooperate for compact design

OILGEAR engineers, pioneering Fluid Power Pumps and Motors, achieved greater compactness and efficiency than ever before considered possible. KAYDON Engineers, pioneers in Thin-Section Precision Bearings, created bearings that were "right at home" at the high level of OILGEAR advanced design.

KAYDON Precision Bearings and Needle Rollers have helped many machinery builders achieve modern design with fewer parts, greater compactness, reduced weight, precision smoothness in operation . . . advantages that improve production, cut costs, and carry impressive sales appeal.

OILGEAR This exploded view shows KAYDON Front and Rear Roller Rotor Bearings with relation to other parts of the 150 hp OILGEAR Fluid Power Variable Delivery Pump (above) for machinery with operating-pressures up to 3000 pounds per square inch . . . with smooth, quiet, startlingly new fluid power performance characteristics. KAYDON Bearings are used also on 60 hp and 100 hp OILGEAR Fluid Power pumps.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

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PRECISION BALL AND ROLLER BEARINGS

Revere takes the DANGER out of refueling operations

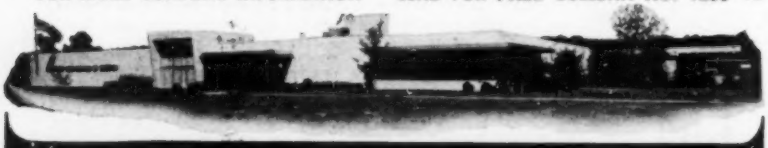
SINGLE AND DUAL FLOAT SWITCHES

Automatic cut-off control

. . . for single point, high pressure fueling and air to air refueling

Revere float switches are available in many different configurations, some of which include relays to handle heavy electrical loads. Others are designed for complete submersion in fluids. The hermetically sealed switch and balanced float assembly minimizes false alarms caused by vibrations or acceleration forces. These units are unaffected by altitude or other pressure and temperature changes. Switches can be provided with a single level or dual level system set at factory at any distance between 1" and 18" from the mounting flange.

FOR MORE COMPLETE INFORMATION SEND FOR FREE BULLETIN NO. 1200 PE



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WALLINGFORD 2, CONNECTICUT, U.S.A.
another precision instrument for aircraft and industry

electrical equipment where manual or mechanical multiple circuit control is required.

The assemblies are available with from one to 10 double-throw switching elements, all operated by a single lever. The lever may be detented in the center, and either or both extreme positions, or may be self returning to the center. The toggle lever has a travel of 30 deg max, in each direction from the neutral position, and is self-returning to the neutral position.

Each switching element is listed at 10 amp up to 250 v a-c, and will handle 30 v d-c inductive loads at 10 amp at sea level and 6 amp at 50,000 foot altitudes.

Micro Switch, Freeport, Ill.

Easy Mounting Oil-Filled Capacitors

A line of easy mounting single-stud tubular oil-filled capacitors of 8 mfd. (600 vdc.), dual 4 mfd. (600 vdc.), 4 mfd. (1000 vdc.), and similar units of the same case size is said to make this one of the most extensive series now available in this class of capacitors.

Known as the *G* and *H* Types, the capacitors are oil-impregnated and filled with Indco Oil *A*. Pyroteen filled capacitors also available. Standard capacity tolerance: +20 to —10 percent. Temperature range: (Indco Oil), —40 to 70 C; (Pyroteen), —70 to 90 C. Power factor: (Indco Oil), 0.4 percent; (Pyroteen), 0.2 percent.

Both models are advantageous

where chassis space and ease of mounting are prime factors. The molded mounting neck is locked in the capacitor case so that capacitors will meet salt water immersion requirements. They are supplied with solid nuts and lock washers for mounting.

Industrial Condenser Corp. 3243 N. California Ave., Chicago 18, Ill.

MEETINGS

January 12-15

AMERICAN MANAGEMENT ASSOCIATION—General Management Conference, Hotel Statler, Los Angeles, Calif.

January 12-16

SOCIETY OF AUTOMOTIVE ENGINEERS—Annual Meeting and Engineering Display, Sheraton-Cadillac Hotel, Detroit, Mich.

January 19-22

PLANT MAINTENANCE CONFERENCE AND SHOW—Public Auditorium, Cleveland, Ohio.

January 23

MALLEABLE FOUNDERS' SOCIETY—General Meeting, Hotel Cleveland, Cleveland, Ohio.

January 26-29

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS—Annual Meeting, Conrad Hilton Hotel, Chicago, Ill.

January 26-30

INTERNATIONAL HEATING AND VENTILATING EXPOSITION—International Amphitheatre, Chicago, Ill.

February 3

AMERICAN ASSOCIATION OF TEXTILE TECHNOLOGISTS—Annual Convention and Exhibition, Hotel Statler, New York, N. Y.

February 4-6

WESTERN COMPUTER CONFERENCE—First Meeting, Hotel Statler, Los Angeles, Calif.

March 16-20

NATIONAL ASSOCIATION OF CORROSION ENGINEERS—1953 Conference and Exhibition, Sherman Hotel, Chicago, Ill.

March 17-26

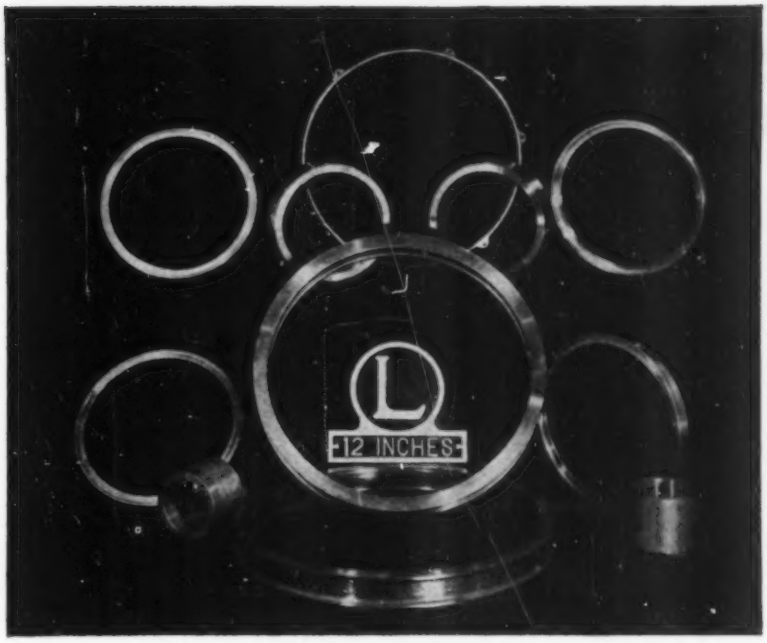
ROYAL NETHERLANDS INDUSTRIES FAIR—Utrecht, Holland.

March 23-27

AMERICAN SOCIETY FOR METALS—Western Metal Congress and Exposition, Pan-Pacific Auditorium, Los Angeles, Calif.

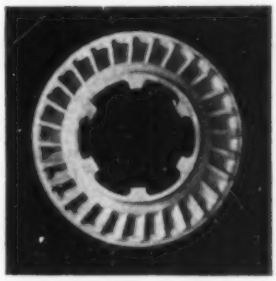
March 31-April 2

MAGNESIUM ASSOCIATION—International Magnesium Exposition, Washington National Guard Armory, Washington, D. C.



to answer the HOT question... specify LEBANON HEAT-RESISTANT Centrifugal Castings

CYLINDRICAL shapes cast in permanent molds by the exclusive Lebanon CENTRI-DIE process, are succeeding where other castings have failed. There are important reasons why Lebanon is able to produce these tough, service-proved castings with such outstanding qualities. First . . . *Lebanon experience*, covering some 41 years, has taught us how to work with difficult-to-cast heat and corrosion alloys. Second . . . *Lebanon testing* involves every proved method (including the use of a million-volt X-Ray machine) to insure absolute structural integrity. Third . . . *Lebanon exclusive processes*, like our CENTRI-DIE method of casting, were developed to give castings superior physical properties, more uniformity and to retain high resistance to many types of destructive agents. For example, today's jet engines which are subject to extremely high temperatures, depend upon Lebanon CENTRI-DIE castings. Lebanon Castings can be made to meet A.I.S.I., A.S.T.M., A.M.S., Army and Navy specifications.



Write for your copy of the Lebanon CENTRI-DIE Bulletin so that you may have, at first hand, all the facts on this important process.

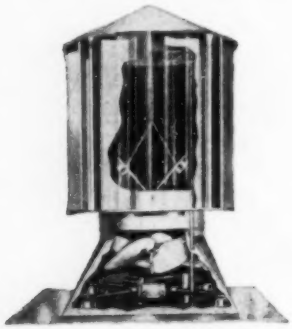
LEBANON STEEL FOUNDRY • LEBANON, PA.
"In the Lebanon Valley"

Other Lebanon quality products include centrifugal castings produced in refractory molds—illustration shows a typical casting made by this process.

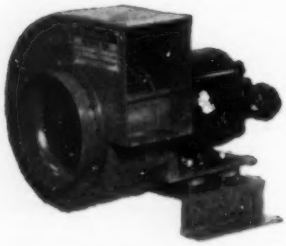
LEBANON Castings
ALLOY AND STEEL

SHOCK AND VIBRATION NEWS

Exhaust Fans Quieted by Vibration Isolators



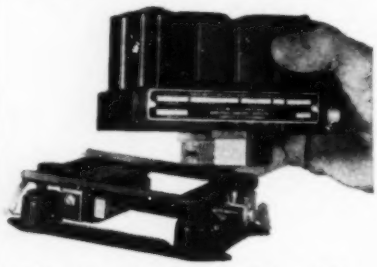
The problem of motor and fan noise is successfully overcome in the Breidert Air-X-Hauster by use of four air-damped Barrymounts that support the low-speed motor and fan assembly. These isolators absorb the motor and fan vibration, keeping it from reaching building members or metal ducts along which it would otherwise be carried or amplified. To assure adequate isolation, the mountings used were type 990 Barrymounts having a natural frequency of only 8 cps.



Another example of use for Barrymounts in ventilating systems is with the high-speed Westinghouse-Sturtevant multi-vane, railway car fan. Here they isolate fan vibration for quieter operation and protect the assembly from the shocks incidental to mobile service. In this application, type C-2000 Barrymounts were used to provide protection against forces applied laterally as well as vertically.

Your vibration or noise problem may be solved by a simple application of Barrymounts. Ask our Field Engineering Department; they'll gladly help you. Or write for Catalog 504-B, describing Barrymounts for a wide variety of uses.

Miniaturized Vibration Isolators Help Cut Space and Weight in Fuel-Gauge Power Unit



70% size reduction and 50% weight reduction — with no loss of performance — is the effective miniaturization obtained in the new Minneapolis-Honeywell aircraft-fuel-gauge power unit. Miniature, air-damped Barrymounts, Type 6465, helped M-H engineers in this achievement.

These vibration isolators, in which size and weight have been cut while operating characteristics have been maintained, will help you redesign for miniaturization.

Check these useful features of miniaturized Barrymounts.

Light weight — only 5/16 ounce each.

Small size — 1" diameter 11/32" loaded height.

Resonant frequency — 9 cps

Transmissibility at resonance — 3

Wide load range — 0.1-3 pounds

4 different styles available — for plate or stand-off mounting.

Write for data sheets 605 and 606 giving details of dimensions and load ratings.

FREE CATALOGS

- 523-A — Air-damped Barrymounts for aircraft service; also mounting bases and instrument mountings.
- 509-A — ALL-METL Barrymounts and mounting bases for unusual airborne applications.
- 504-B — Shock mounts and vibration isolators for marine, mobile, and industrial uses.
- 607 — How to cut maintenance costs by using Barrymounts with punch presses.

THE **BARRY** CORP.

730 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

SALES REPRESENTATIVES IN

Atlanta Chicago Cleveland Dallas Dayton Detroit Los Angeles Minneapolis New York Philadelphia Phoenix Rochester St. Louis San Francisco Seattle Toronto Washington

Sans, Souci

Ad Libbing by the Editor

All of us are little men when we begin our business career. All of us grow to some degree. Some of us grow clear up to the top, most of us half way between and a few never get anyplace. In my work as editor I have to do a lot of visiting. Many years ago when I first started in my editorial career I paid a visit to a certain company. Naturally I called upon the publicity manager of that company.

Now it just happened that this particular publicity manager, we will call him Elmer, had just been put into the job. He was a little pipsqueak with a big mop of hair. The first thing he did was to keep me waiting twenty minutes although I had a definite appointment with him. Then I was allowed to enter into his pompous presence. He was very domineering in his attitude, spoke with his chest thrown out and did everything possible to impress me. I called on that plant only a few months ago. Elmer is still there, in the same old job. He doesn't have quite as much hair and his chest has grown kind of flat. But he is still as pompous as ever.

He reminded me of a visit I made one time to the office of William C. Dickerman. He at that time was Vice President in Charge of Engineering and Production at the American Car & Foundry Company. At that time I was a college professor and I had done some work for the American Car & Foundry Company and Mr. Dickerman had written me and asked me to come to New York to see him in order to discuss some matters with him. A definite appointment was made for a certain day and hour and at the appointed time I arrived. Mr. Dickerman had a male receptionist whose name I was afterwards to learn was Tom. When I presented myself to the receptionist he said, "I am sorry Mr. Dickerman is in conference." Instead of telling Tom that I had an appointment I asked him, "When do you expect the conference to finish?" The reply was that it was a meeting of the district managers, the conference would probably last all day and wouldn't be over until late in the afternoon. I then referred to my appointment. Immediately Tom was filled with apologies. He opened the date book and saw that a mistake had been made in entering the date of the appointment. He explained to me how

it came about and told me to sit down for a moment in the reception room. I did that. Tom went out, came back shortly and told me that Mr. Dickerman would see me in a moment. And in only a few moments Mr. Dickerman came out. He also apologized and told me that he had made arrangements to absent himself from the meeting for a matter of half or three-quarters of an hour and that I should take plenty of time and feel perfectly at ease in telling me what he wanted to know.

What a difference. Incidentally, five years later Mr. Dickerman was no longer a vice president of the American Car & Foundry Company. He was made President of the American Locomotive Company and later became chairman of the board. All of this effectively illustrates the difference between a big man who is humble and a little man who wants to act big but doesn't know how.

Apples and Whitewash

Mark Twain was a great humorist and an even greater student of human nature. Though his most famous books dealt with the boys Tom Sawyer and Huckleberry Finn, he used those juvenile characters to mirror the foibles and frailties of adults as well.

People of all ages will always laug'i about the trick that Tom Sawyer played in getting the fence whitewashed. For the payment of an apple, a penny, a frog or some other bauble he would permit the boys to paint a board or two. Thus he not only got some one else to do his job but he even made them pay him for the privilege.

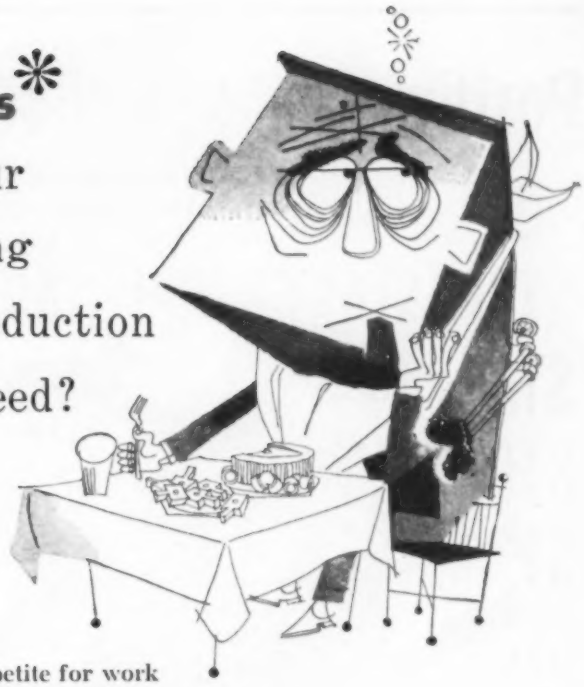
Men chuckle when they read the story and say to themselves, "Just like boys", and honestly believe that never would they be such suckers. The next night they find themselves stooging on somebody's radio program. They give no thought to the fact that the fellow putting on the program is getting paid a few thousand dollars. That does not enter into their thinking. They love to "whitewash", be in the limelight, give of their time, be willing to be made the butt of a joke, and proudly proclaim they did it for only fun.

Every good citizen should feel willing to be Tom Sawyered into doing a worthy non-commercial task of a religious or social nature. But when it comes to whitewashing fences or frying fish, that is another matter. Yet we see professional societies sponsoring commercial ventures that are questionably "for the good of the profession in furthering its aims." And the members whitewash the fence.—GFN

does

coil-itis*

have your processing tank production off its feed?



When the appetite for work of your heating and cooling processes diminishes, the trouble may well be coil-itis. For, downtime due to pipe failures and limitations can seriously delay your production flow. Switch to Platecoils, the new tonic for production, as revolutionary as the new wonder drugs. Platecoils take 50% less tank space leaving more room for greater payload. They heat or cool 50% faster. They simplify maintenance and save hours of downtime. Equally important, Platecoils cost as much as 50% less in the first place. Platecoils cure production troubles involving heat transfer and give production a shot in the arm.

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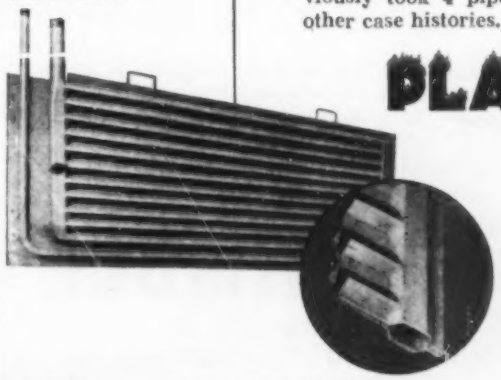
PLATECOILS SAVE 50% IN HEAT TRANSFER COSTS

PLATECOILS ELIMINATE A 6-TO-8 HOUR-A-DAY CHIPPING JOB



At Sealed Power Corp., installation of Platecoils has completely eliminated a 6-to-8 hour-a-day chipping job. Three Platecoils now heat a tank that previously took 4 pipe coils. Ask about other case histories.

PLATECOIL

REPLACES PIPE COILS

Coil-itis — Diagnosed as tank heating and cooling problems. Platecoils — the prescription for solving pipe coil problems.

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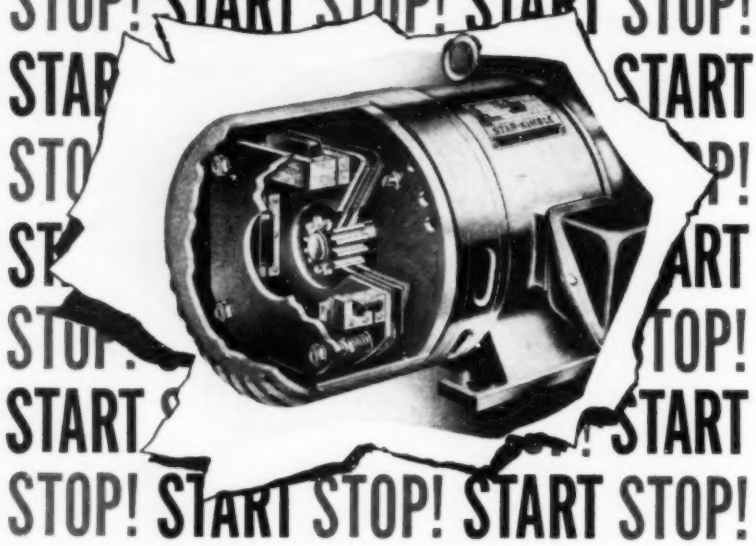

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NOTE THE EXTRA-LARGE BRAKELINING AREA—discs machined on both sides to give full, positive contact—that brings a Star-Kimble Brakemotor *and its connected load* to the same sure fraction-of-a-second stop through *millions of operations.*

NOTE THE SMALL AIR GAP between electromagnets and brake armature disc. It assures quick brake release—allows the load to start freely when the motor is energized.

COMPARE THE REVERSING CYCLE of a Star-Kimble Brakemotor and a motor reversed by conventional plugging. Typical figures on maximum starts per minute for a 5 hp motor: with plug stops, *three;* with the Star-Kimble way, *ten!*

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For information on design and service features, write for Bulletin B-501-A

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MOTOR DIVISION OF
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211 Bloomfield Avenue Bloomfield, New Jersey

ENGINEERING ABSTRACTS

Advances in Aluminum

Abstracted from "Aluminum Advances in . . . Brazed Castings, Plaster Castings, Die Castings, Wiring, Finishes" by J. H. Dunn and E. P. White, *SAE Journal* September, 1952.

MAKING A COMPLICATED CASTING requiring intricate cores is a pretty expensive proposition. One way out is to make a series of simple castings which can be joined by brazing.

Dividing the casting into simple, easy-to-make, high-production section and brazing them together, eliminates many problems.

Success of the assembly of aluminum castings by brazing depends on the availability of a suitable alloy. The material must lend itself to brazing, and also have the necessary qualifications for the part being produced—such as strength, resistance to corrosion, good machinability, satisfactory foundry characteristics, and low cost.

The aluminum alloy that best meets these requirements is Alcoa C612. With a nominal composition of 6.5 percent zinc, 0.5 percent copper, 0.35 percent magnesium, balance aluminum. This alloy does not require heat treatment; it gets its very respectable properties after room temperature aging of approximately 30 days.

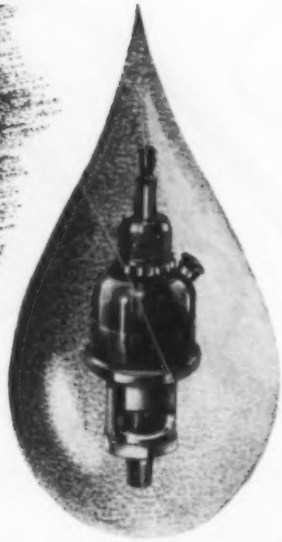
The flux-coated brazing sheet is sandwiched between the layers of casting, and the assembly held in alignment by jigs, pins, formed tips on the brazing sheet, or other suitable means during brazing.

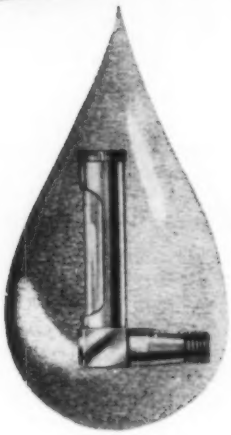
Successful brazing calls for the maintenance of a definite clearance between the parts to be joined. One way of doing this, is to use small washers of 2S alloy 0.010 in. thick between the layers of castings. The melting point of 2S is higher than that of the brazing material. That establishes a joint clearance and prevents the squeezing out of the brazing material by the weight of the castings.

Other methods—such as knurling, corrugating the surface, or mixing small aluminum shot with the flux—have also proved satisfactory for establishing the clearance necessary for good brazing.

After furnace brazing, the assembly is allowed to cool to a temperature of approximately 900 F, assuring solidification of all brazing material. The

For Lubricating Devices Call On GITS First!





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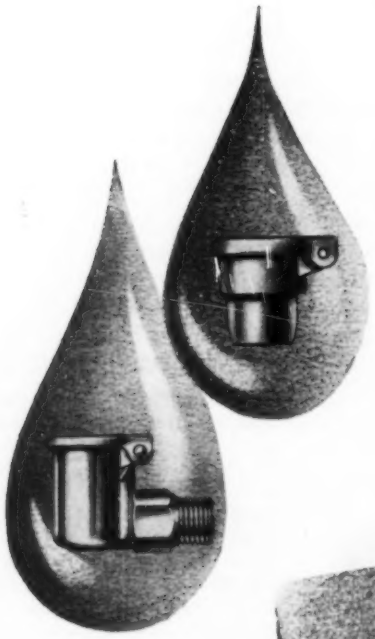

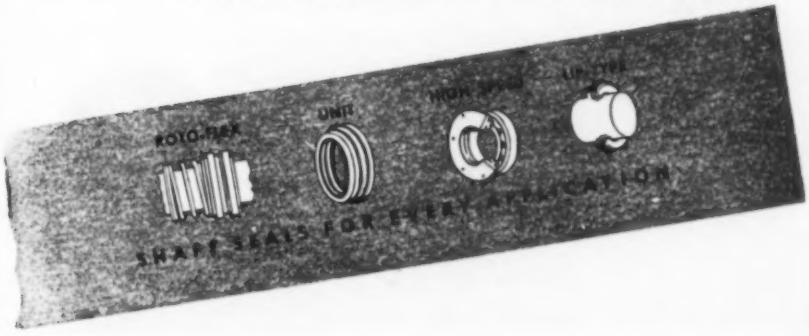

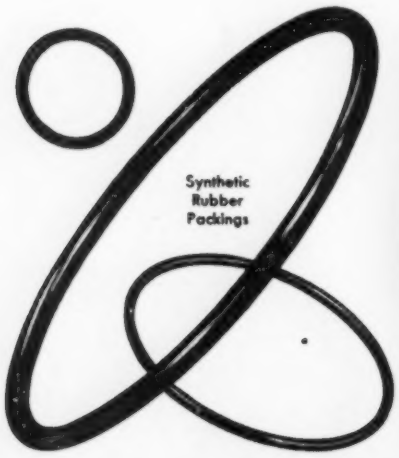

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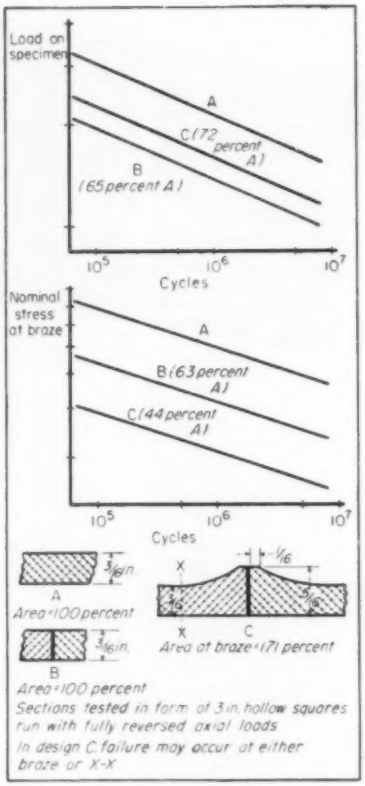

FATIGUE TESTS of brazed joints produced these results comparing the fatigue strength of parent metal and beaded and unbeaded brazes.

assembly is then quenched in water and held at about 180 F. Final cleaning is done in a solution of nitric acid of 58 percent concentration at room temperature, followed by hot water rinse.

Lab tests show that brazed joints have a strength 65 percent of that of the parent material; with a ribbed construction this strength is increased to 72 percent.

Die Castings for Structural Use

Aluminum die castings have been used for many years in automotive parts, but few have been used for structural applications. One reason for this has been that although some aluminum die casting alloys have excellent test bar properties, these properties could not be consistently obtained in actual castings. In an effort to get factors which may ultimately be used in relating "book" or laboratory data to actual performance, a test program was undertaken.

Comparisons between sand castings and die castings are shown in Table I. The die castings show a greater drop in properties percentage-wise in the

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NEW TIME TOTALIZER
MODEL ET

better than 0.2 of 1% accuracy

Designed to the most exacting specifications for such applications as timing operations in industrial laboratories or for measurement processes in the chemical and metals industries. Incorporates new principle of differential clutching that prevents slippage and overrun and insures unusually high accuracy and dependable performance.

FEATURES

- *High Accuracy*... Better than 0.2 of 1% of full scale reading.
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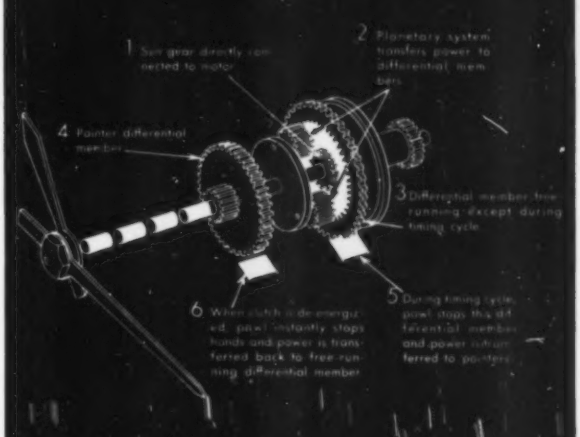
POSITIVE ACTION CLUTCH *WITH DIFFERENTIAL GEAR* PREVENTS SLIPPING OR OVERRUN


1 Sun gear directly connected to motor
2 Planetary system transfers power to differential members
3 Differential member free-running except during timing cycle
4 Pointer differential member
5 During timing cycle, pawl stops this differential member and power is transferred to pointer
6 When clutch is de-energized, pawl instantly stops hands and power is transferred back to free-running differential member

In this unique clutch mechanism, the motor is permanently connected to the sun gear of a differential gear system. A solenoid pawl moves between the two differential members so that only one is free to rotate at one time. Starts and stops are thus effected by positive engagement of pawl with gear. There can be none of the slippage or overrun associated with friction clutches, nor can characteristics change with age.

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A COMPLETE LINE OF PUMPS, PUMPING UNITS, FLUID MOTORS, CONTROLS

Table I—Comparative Properties of Aluminum Die Castings and Sand Castings

Material	Die Cast Alloy 380	Sand Cast Alloy 356-T71*
Typical Properties:		
Tensile Strength Psi	45,000	28,000
Yield Strength psi	26,000	21,000
Elongation percent in 2 in.	2.0	3.5
Fatigue Tests		
Rotating Beam, psi	20,000	10,000
I Beam, psi	9,000	6,500
Static Test Breaking Load, lb	5,310	5,950

* Machined from standard, specified test bars.

fatigue tests; but they still are stronger in fatigue, and compare quite favorably in actual static breaking load tests.

Plaster Castings

Parts for many torque converters are made by the plaster casting process. The process in itself is not new, although many techniques responsible for bringing it to the current production stage have been developed within the last two or three years.

An outstanding advantage of the current plaster process is common to other methods of investment casting: the making of intricate parts with back drafts, or re-entrant sections, which can be made by practically no other commercial casting procedure. Coupled with this ability are also the desirable attributes of close dimensional tolerances and excellent surface finish.

All three advantages form a fortunate combination for the production of torque converter parts.

Finish Applications

Generally speaking, aluminum can be finished with all the presently used metal, finishing techniques plus additional anodic finishes suited particularly to aluminum. Metallurgical considerations are of great importance in all cases.

Anodic coatings on aluminum have been developed to a higher degree than on any other metal and provide a particularly useful finish. Anodic coatings developed by Alcoa have been given the trade name of Alumilite. Since it is a conversion coating, the transparency of an Alumilite coating is directly related to both alloy and temper. Alzak reflectors, widely used in the field of illumination, are made

with a high purity clad sheet anodically coated.

For most uses other than reflectors, however, a certain amount of strength is required along with varying degrees of lustre. Here is a problem of maintaining the clear finish of high purity aluminum while increasing strength and, in some cases, changing the lustre through the addition of alloying elements. A solution to the problem was provided by the development of Alcoa 63S, alloy which has been widely used for extrusions with bright Alumilite finish.

Thus far only the wrought alloys have been considered. As might be expected, however, metallurgical considerations are as important for the cast alloys as they are for the wrought alloys in achieving a wide variety of finishes. Die cast aluminum parts have recently received special attention in this regard, both since die castings in general are widely used for automotive hardware and since the nature of the die casting process creates additional problems.

Current metallurgical research has brought out Alcoa Alloy XA214 die castings. This alloy has a nominal composition of 3.8 percent magnesium and 1.8 percent zinc. With this composition, the effect of flow lines is minimized and a more lustrous finish results.

For functional use of the Alumilite process, such as the hard Alumilite coatings, alloy selection is just as important as it is for decorative applications. Here, alloys must be chosen which result in a very dense oxide coating. Hard Alumilite coated pistons, impellers, and gears are currently in production.

Metal-Wood Adhesives

Abstracted from "Adhesives for Bonding Wood to Metal," by H. W. Eickner and R. F. Blomquist, *Forest Products Laboratory Report No. R1768.*

THE THREE MAIN GROUPS OF WOOD-METAL ADHESIVES are: (1) the direct-bonding, high-temperature-setting; (2) the two-step-bonding with adhesive primer and secondary adhesive; and (3) the direct-bonding, room-temperature-setting groups.

A large group of the metal-bonding adhesives is included in the direct-bonding type that require curing of the bond under pressure at temperatures ranging from 250 to 350 F. Adhesives of this group are usually composed of at least two resins, a thermoplastic resin or elastomer, such as polyvinyl formal, or a synthetic rubber,

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4 models, 1/2" to 1 1/2" sizes . . . 3000 psi maximum
Standard Subplate or Threaded Body Types

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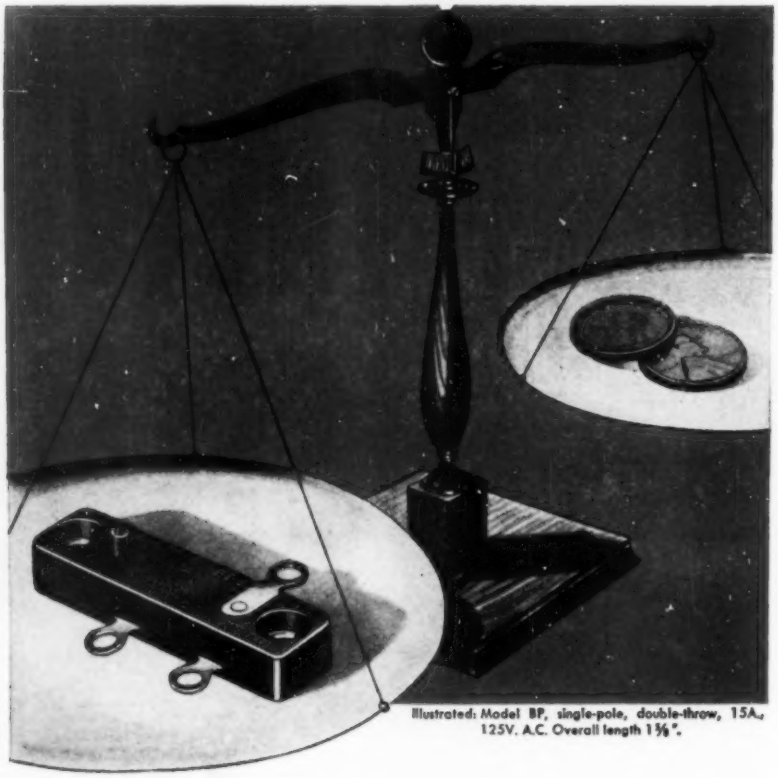


Illustrated: Model BP, single-pole, double-throw, 15A., 125V. A.C. Overall length 1 5/8".

The only miniature snap switch

where size and high rating come to terms with cost

Repeat: *where size and high rating come to terms with cost.* Consider this in terms of engineering that seeks to increase product efficiency while holding costs at a minimum. Then base your snap switch specifications on the following facts.

TYNISWITCH is a low cost, compact snap-action unit based on simplified construction principles. It permits high-load switching in a minimum amount of space. It eliminates costly, nonfunctional bulk in new or redesigned products. No other model or make — of comparable size and rating — can match its high-standard performance. Its action is flawlessly smooth and dependable. Moreover, it has been conclusively proven by approved laboratory tests that TYNISWITCH is completely reliable at high operating speeds . . . for over millions of cycles!

Investigate these and many other TYNISWITCH advantages today. New models can be developed economically to fit your speed and specifications—or you can select conventional circuit arrangements from a variety of standard units. Write for details. TYNISWITCH Division, The Sessions Clock Company, 103 East Main Street, Forestville, Connecticut.

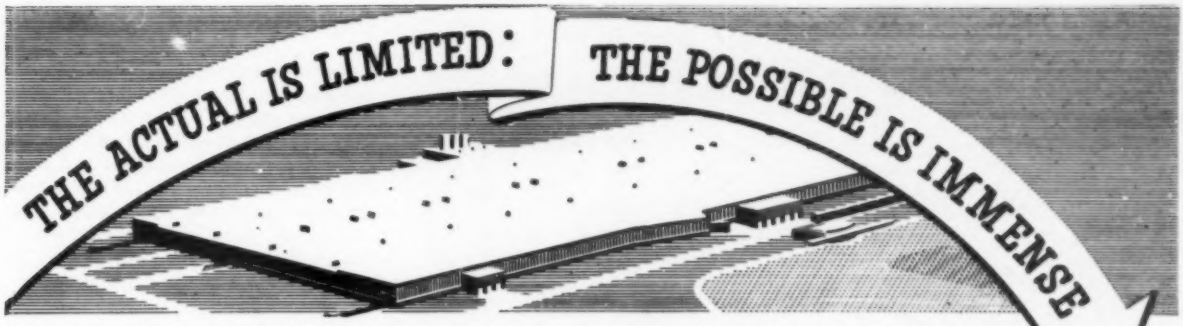
and a thermosetting resin, such as phenol formaldehyde, combined in solvents in such proportions as will provide the necessary characteristics of adhesion to metal, elasticity, flow during cure, heat resistance, and durability of the resultant bonds. In some instances, the two resin ingredients may be applied separately.

In bonding wood to metal with the direct-bonding, high-temperature-setting adhesives, high stresses are developed as the bonds are cooled because of the different coefficients of thermal expansion of the two materials. Stresses are also developed when the wood expands as it regains moisture. These high stresses tend to distort the metal-wood construction and may even rupture the bond if the adhesive is not sufficiently elastic and strong. In hot pressing blistering of the bonds, caused by the tendency of entrapped adhesive solvents to escape, can also occur.

To avoid these limitations of the direct-bonding, high temperature-setting adhesive, as well as to avoid the need for hot-press equipment, a two-step adhesive process was developed. A priming adhesive is applied to the metal and cured at elevated temperatures in an oven or on the platens of a hot press without pressure, and the cure primer is bonded to the wood with room- or intermediate-temperature-setting urea-, resorcinol-, or phenol-resin adhesives of the woodworking type.

The third group of metal-bonding adhesives includes those adhesives capable of forming direct bonds to metals at room temperatures. At the present stage of development, joints of metal to wood made with the available room-temperature-setting adhesives do not have the over-all strength at room and elevated temperatures, and after soaking in water and aircraft fluids, of those made with the hot-setting and two-step adhesives. The casein-rubber-latex adhesives have been used successfully at room temperatures for bonding wood to metal for those applications that are not so critically stressed as aircraft construction, but these adhesives usually have the disadvantage of losing a large part of their strength when the bonds become wet or are exposed to high humidity. Recently, some room-temperature-setting adhesives have been formulated with epichlorohydrin resins, but it is not known if these adhesives will maintain their bond strength when wet or when stressed at elevated temperatures.

In addition to the room-temperature-setting wood-metal adhesives mentioned above, there are a number of



NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

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WELDED STEEL DESIGN CUTS MANUFACTURING COSTS

. . . saves machining, simplifies production

MANY types and sizes of machine components can be produced more efficiently . . . with less material . . . at less cost through welded steel design. From heavy equipment like large presses (Fig. 1 & 2) to small machines (Fig. 3 & 4), proper design in welded steel saves materials, saves labor . . . cuts cost.

Material costs are less with welded steel designs because fewer pounds of metal are required on which less machining and less finishing is necessary. Products have better selling appeal with welded steel's modern appearance.

Fig. 4. Original Construction *of marking machine. Had high rejection rate in castings. Required considerable machining and finishing. Weighed 83 pounds.*

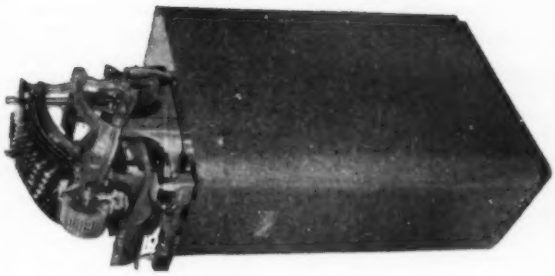

Fig. 3. Welded Design. *Cuts manufacturing cost 25%, weighs 33% less. Cabinet type base is now fabricated from 16 gauge metal and welded in simple fixture. Steel design eliminates entire cost of machining and handling originally required.* Courtesy National Marking Machine Company, Cincinnati, Ohio.

PROPER DESIGN IN WELDED STEEL IMPROVES PRODUCT AND LOWERS COST

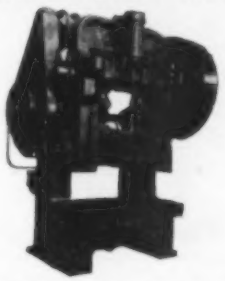

Fig. 1. Original Construction *of multiple punch press. Material cost was $.10 per pound from this manufacturer's own foundry. Weight was 56,000 pounds.*

INCREASES RIGIDITY SAVES MATERIAL

Fig. 2. Welded Steel Design *is actually more rigid than former casting yet weighs only 49,550 pounds. Modern in appearance . . . costs 15% less.* Courtesy Williams-White and Co., Moline, Illinois.

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mastic and solvent-type adhesives for bonding wood to metal at room temperatures at only a low intitial pressure. These adhesives generally produce joints with considerably lower strengths than joints made with the adhesives previously mentioned. For this reason, these mastic and solvent-based adhesives are intended primarily for applications where high strengths are not required.

Wood surfaces should be free of all dirt, wax, grease, and oil, and the machining of the surfaces should be such that uniform pressures will be obtained when the joint is assembled and the pressure applied.

Applying the Adhesives

Adhesives can be applied to the surfaces with any convenient device—brush, hand roller, conventional glue spreader, gear-type applicator, spray gun or dip tank—that will spread the adhesive uniformly. The conditions during adhesive application are more critical with the wood-metal adhesives than with the woodworking adhesives, because many of the wood-metal adhesives have little flow during the bonding cycle, and, therefore, any resultant irregularities in the adhesive film are likely to cause some low-pressure areas in the bonds that, in turn, will result in joints of low strength.

Each adhesive manufacturer usually recommends the bonding time and temperature for use with his adhesive because these depend on the formulation of the adhesive. Most direct-bonding, high-temperature-setting adhesives with a synthetic-rubber base should be cured at temperatures of 325 F or higher, but some can be cured at 300 F. Some vinyl-modified, high-temperature-setting adhesives can be cured at temperatures as low as 240 F, but in general adhesives of this type are cured at temperatures of 300 to 315 F. Typical curing periods for several of these adhesives at 300 F or higher vary from 15 to 30 minutes.

When these adhesives are used as metal primers in the two-step bonding process, curing temperatures can be the same as used for direct bonds. Secondary adhesives used in two-step bonding can be cured under the conditions normally used with these adhesives in woodworking, but in some instances the curing of these adhesives at slightly higher temperatures than normally used for wood bonding has resulted in stronger bonds.

The casein-rubber-latex room-temperature-setting adhesives generally require 10 hr for pressing at normal room temperature.

A pressing period of 24 hr at nor-

mal room temperature is apparently required before bonds made with the present epichlorohydrin-resin adhesives can be safely handled, and 4 or 5 days of conditioning are required before bonds made with them will reach full strength.

Original Bond Strength

In evaluation tests made with a lap-joint specimen of three-ply, $\frac{3}{16}$ in. birch plywood and 0.032 in. clad aluminum alloy and with a three-ply type of specimen of $\frac{1}{16}$ in. birch veneer core and 0.032 in. clad aluminum alloy faces failures in the birch of 75 to 100 percent are usually obtained when bonding with the high-temperature-setting adhesives having a base of vinyl resin, and 25 to 65 percent when bonding with the high-temperature-setting rubber-base adhesives or with the two-step bonding processes. When woods of lower density are used, failures with all of these types of wood-metal adhesives are almost completely in the wood indicating a successful joint.

Failure loads obtained with these specimens bonded with the better wood-metal adhesives generally ranged from 650 to 900 lb per sq in. for the 1 in. plywood type aluminum and birch specimen and from 1,300 to 1,800 lb per sq in. for the $\frac{1}{2}$ in. lap-joint of aluminum and birch plywood. A few of the high-temperature-setting adhesives with high percentages of vinyl resins produced joints having slightly higher strengths. This increase may have been caused by relief of certain stresses in these more elastic joints under the test conditions used.

Bonded lap joints of steel to birch plywood and of aluminum to birch plywood made with several bonding processes were exposed for periods up to 1 year at a temperature of 158 F and 20 percent relative humidity and then tested at 80 F. Under these conditions most of the structural wood-metal adhesives were found to maintain their initial joint quality. Most of the decrease in strength that did occur can be attributed to the weakening of the wood, since the joint failures were mainly in the wood. The one exception noted was in bonds to steel made with a high-temperature-setting adhesive having a rubber base. With this adhesive, the joints decreased decidedly in strength after 32 weeks of exposure, and the failure was mainly in adhesion to the steel. The loss of strength in this case appeared to be caused more by a corrosion of the steel than by the effect of the temperature on the adhesive.

Similar exposure tests were also made on bonded lap-joint specimens

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Technical Service Data Sheet
Subject: INDEX OF ACP CHEMICALS FOR METAL PRESERVATION AND PAINT PROTECTION

METAL	OPERATION	ACP CHEMICAL
ALUMINUM	Cleaning	"DEOXIDINE" "DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Preparation for Painting	"ALODINE" "DURIDINE" "DEOXIDINE"
	Protection from Corrosion	"ALODINE"
BRASS	Brightening	"ACP BRIGHT DIP"
	Cleaning	"DEOXIDINE" "DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Cleaning for Painting	"DEOXIDINE" "CUPROTEK
	Corrosion Prevention	"CUPROTEK"
	Soldering Flux	"FLOSOL"
COPPER, BERYLLIUM, AND COPPER ALLOYS	Brightening	"ACP BRIGHT DIP"
	Cleaning	"DEOXIDINE" "DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Cleaning for Painting	"DEOXIDINE" "CUPROTEK"
	Coating Steel with Copper	"CUPRODINE"
	Corrosion Prevention	"CUPROTEK"
	Scale Modification	"RIDOXINE"
	Soldering Flux	"FLOSOL"
	Stripping Copper Coatings	"ACP COPPER STRIPPING SOLUTION"
GALVANIZED IRON, ZINC, AND CADMIUM	Cleaning	"DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Corrosion Proofing	"ZINODINE"
	Paint Bonding	"ZINODINE"
	Phosphate Coating, in Preparation for Painting	"LITHOFORM"
	Soldering Flux	"FLOSOL"
IRON AND STEEL	Chromate Coating, in Preparation for Painting	"CROMODINE"
	Cleaning	"ACP RIDOLINES AND RIDOSOLS"
	Cleaning for Painting	"DEOXIDINE" "DURIDINE"
	Coating with Copper	"CUPRODINE"
	Drawing and Extrusion	"GRANODRAW"
	Paint Bonding	"CROMODINE" "DURIDINE" "GRANODINE" "PERMADINE" "THERMOIL-GRANODINE"
	Paint Stripping	"CAUSTIC SODA AND SOLVENT NO. 3"
	Phosphate Coating, in Preparation for Painting	"DURIDINE" "GRANODINE" "PERMADINE" "THERMOIL-GRANODINE"
	Phosphate Coating, to Protect Friction Surfaces	"THERMOIL-GRANODINE"
	Pickling with Inhibited Acids	"RODINE"
	Rust Prevention for Unpainted Iron	"PEROLINE"
	Rust Proofing	"PERMADINE" "THERMOIL-GRANODINE"
	Rust Removal—Brush, Dip, or Spray	"DEOXIDINE"
	Soldering Flux	"FLOSOL"
MAGNESIUM	Cleaning	"DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Pickling	"RODINE (M-200)"
STAINLESS STEEL	Cleaning	"DEOXIDINE"
	Coating with Copper	"CUPRODINE"
	Pickle Polishing	"RODINE"
	Soldering Flux	"FLOSOL"

CHEMICALS ACP PROCESSES

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CHEMICALS ACP PROCESSES

of birch and metal that had been exposed up to 1 year to repeating cycles of 1 day at a temperature of —67 F, followed by 1 day at 158 F and at 20 percent relative humidity. The results obtained were similar to those obtained in continuous exposure to 158 F.

Lap-joint specimens of birch plywood and aluminum heated to 200 F and tested at once at this temperature maintained 50 to 90 percent of their room-temperature strength. The bonds that lost most strength were those made of adhesives with a high content of thermoplastic vinyl resins.

Cost and Stress Factors In Aluminum Structural Design

Abstracted from "Cost and Stress Factors in Aluminum Structural Design" by Edmund R. Baetzel, *Modern Metals*, October, 1952.

ALUMINUM COSTS about seven times as much as steel per pound and while aluminum weighs only one-third as much as steel, it is still about two and a half times more costly on a volume basis. In view of the rising price of steel, however, and the relatively stable price of aluminum, this margin of difference is gradually decreasing in favor of aluminum.

Nevertheless, these higher costs mean that unless conditions of service are a criterion in design (light weight for military use, corrosion resistance for large chemical tanks, etc.), the added valuable assets of aluminum could easily be foregone in a competitive commercial market.

In spite of some favorable secondary cost considerations, such as ease of maintenance, handling, etc., the high material cost of aluminum remains the one major obstacle to more extensive structural applications, and must be a major consideration in aluminum design. In many instances, the economic balance can be influenced by the structural designer who, through efficient design practices, can effect substantial reductions in the amount of material and fabrication required.

This can be accomplished through the use of thinner sections than previously experienced in steel design and a redistribution of the material throughout the structure. In other words, a careful stress analysis is required for each section in order to eliminate excess material and place the remaining material where it will do the most good.

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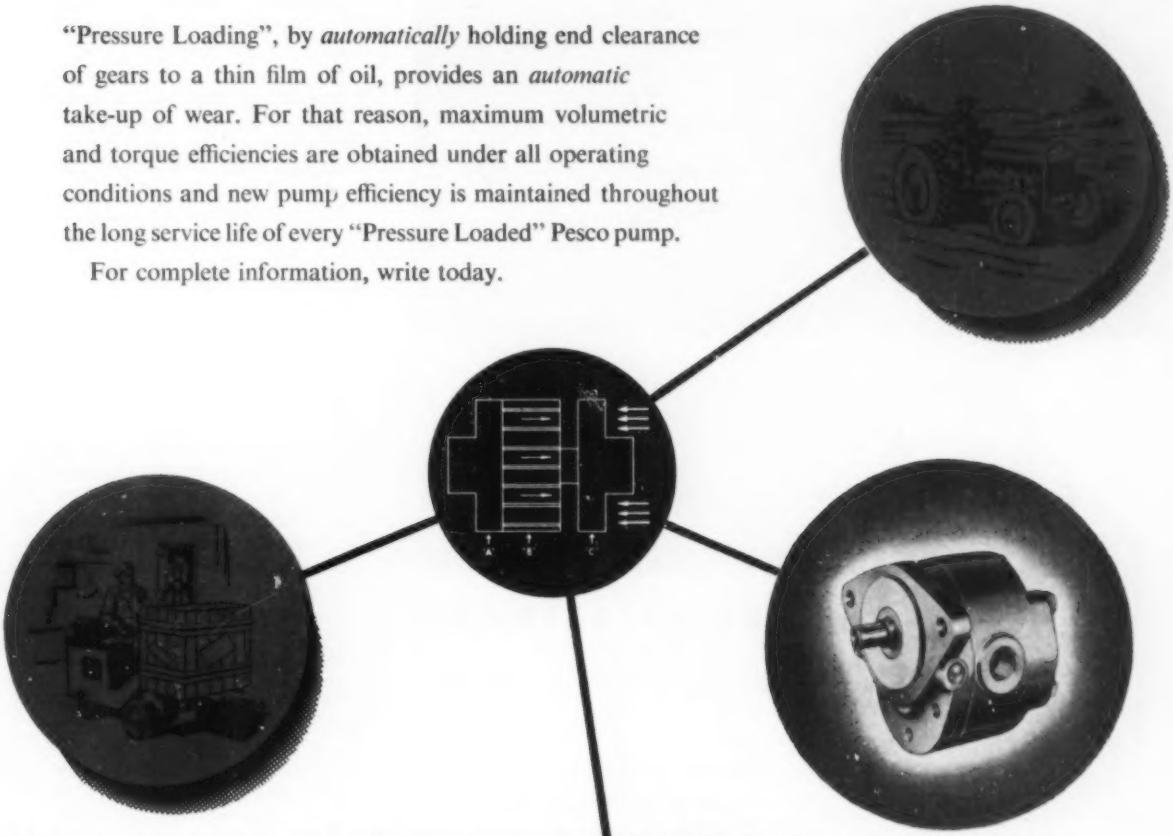

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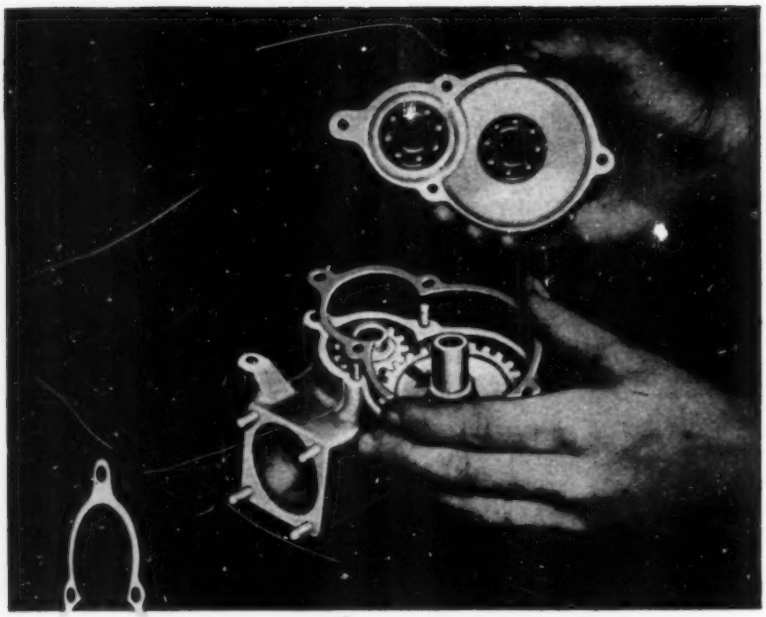

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erties and characteristics of any material is required in order to promote maximum efficiency in design. While the mechanical properties of aluminum alloys and structural steel are similar, the significant differences in their elastic moduli, coefficients of thermal expansion, and other physical properties, as well as their fabrication characteristics, warrant a completely different design approach for each material.

The use of steel design principles cannot be modified to accommodate the so-called "shortcomings" of aluminum and still be conducive to efficient aluminum design. If maximum economy is to be gained by using the strong, light weight but more resilient aluminum alloys, changes will be required in the shapes of the accustomed standard structural steel sections and in the general proportions of the structure.

Instability caused by secondary stresses which result in localized buckling and torsional failure is also possible in steel structures. Because of the fabrication limitations in rolling, however, the flanges of the standard steel sections are so thin that premature failures by local crumpling of the flanges rarely occur and do not usually need to be considered except in special cases such as when deep webs are used in built-up girders.

Which Sections Fail

On the other hand, the favorable fabrication characteristics of aluminum permit the roll forming and extrusion of thinner flanges, which allow an increased radius of gyration for the same area of cross section. It has been reported, however, that not all aluminum sections are prone to such failures in end long compression.

Only the thin flanged angle and tee section and, to a lesser extent, channel sections are conducive to instability. The normally proportioned aluminum I and Z sections used in structural design are similar to steel in that instability failures are quite rare.

When such conditions of failure are likely to occur, the designer should consider the use of special sections or longitudinal stiffeners. Special extruded sections which incorporate relatively large radii at the flange junctions, or bulb angles, which supply added material at the tips of the legs, greatly increase torsional strength and reduce the elastic instability of long slender sections.

While these extruded sections lose some rigidity in handling as compared to roll formed top hats, channels, etc., they are about 10 percent cheaper,

which would offset any increase in material weight.

When considering larger joists and channels, longitudinal stiffeners can be used to great advantage to resist any type of secondary failure other than direct compressive stresses across the flange. Such stiffeners also serve to lower fabrication costs when compared with the usual vertical stiffeners which are employed to prevent plate or webb buckling.

The favorable extrusion characteristic of aluminum is one of its greatest assets in structural applications and should be an effective tool in design. By means of extrusion, a wide variety of cross sectional shapes is available to the designer to effectively combat deflection and achieve lower cost.

Since it is possible to compensate for aluminum's lower elastic modulus by increasing the moment of inertia of a section, or by changing the distribution of material about the neutral axis of a cross-sectional area, extrusion offers a variety of means for stiffening sections.

The designer is not limited in choice to merely increasing the depth of section as in an I beam. He can also select a spatial distribution of material to fit the physical dimensions of a design detail and accomplish the same purpose far more efficiently and economically. In addition, such extrusions can facilitate fabrication and assembly details while serving other functional capacities.

Thus, highly efficient and economical sections are available which help to further minimize high material costs.

Another factor which deserves consideration in design cost is proper alloy selection. The price differential of several cents per pound between the various aluminum alloys can approach very significant figures when large quantities of material are involved. Therefore, each structural component should be thoroughly analyzed for its specific function.

For example, when deflection is the criterion in design, possibly alloy 61S would be entirely suitable rather than the higher strength, more expensive alloys, 24S and 75S. When corrosion is the salient factor, why use the high strength alloy 75S when the corrosion properties of 61S are superior and available at a much lower cost?

Whenever possible, the common alloys, 2S and 3S, offer considerable savings over the heat-treatable alloy 61S for use in storage tanks or other structural components which are not highly stressed. Again a close familiarity with the material he is working with will pay large dividends to the designer.

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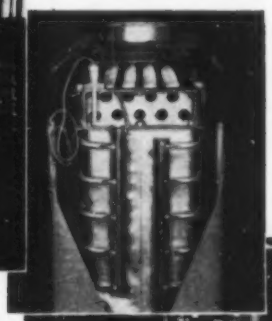

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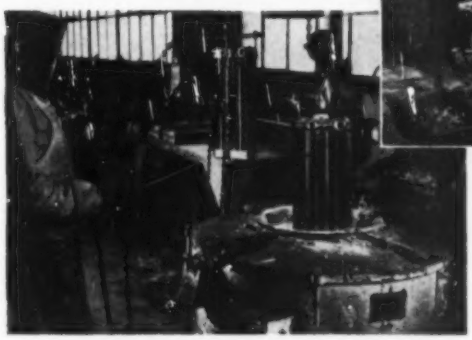

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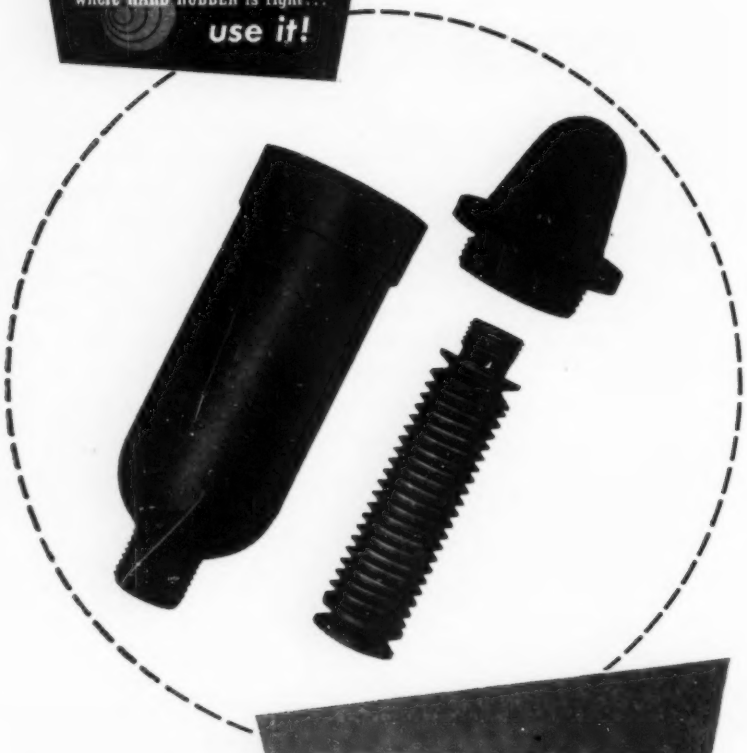

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OUR READERS SAY

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To the Editor:

We have received, and are very much impressed with the Annual Handbook of Product Design for 1953. It will be very useful to us as a reference book as well as a source of Engineering information.

We are particularly interested in the section devoted to Air and Hydraulic Equipment which is the field in which we are active.

We congratulate you on an excellent job very well done.

—HORACE E. THORN
The Battersby Co.

To the Editor:

We wish to express our approval of your new Handbook of Product Design for 1953, which has recently been received.

We think it is an excellent job, and we are routing it through our organization.

—W. H. KNOWLES, JR.
Aircraft-Marine Products, Inc.

To the Editor:

I have just received my copy of the Annual Handbook of Product Design for 1953. I have examined the various features, particularly the way the subjects are segregated in their various sections, and I think that you have done an excellent job and are to be heartily congratulated.

One feature which I like, and which will save a good deal of time is the multiple index where you have the contents and advertising material fully identified in different ways. This feature I am sure will appeal to all of your readers.

—NORMAN ENGLISH, V. P.
Vapor Car Heating Co.
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To the Editor:

We have looked over your new Annual Handbook of Product Design and believe that it will serve as a very valuable reference in our Product Design Department. You are to be congratulated on the manner in which you have presented this material.

To handle our requirements, at least one, possibly two additional copies will be needed. Please advise

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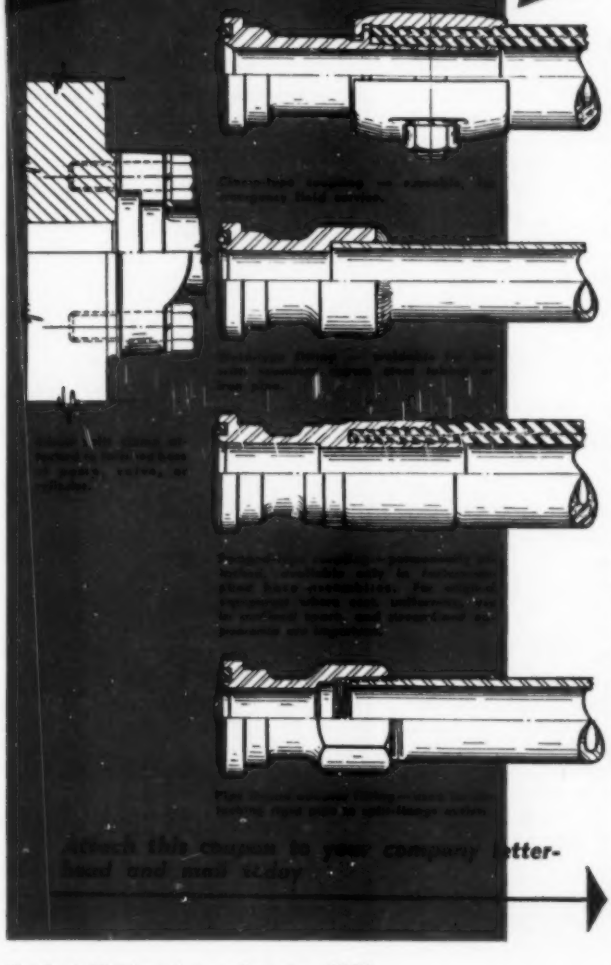

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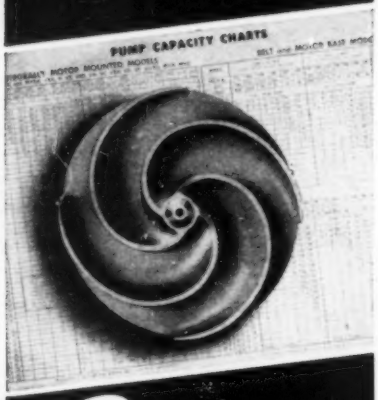

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the exact procedure to be followed in obtaining additional copies. Also, please advise if reprints of most or all of the articles are available.

—A. F. HUBBARD, *Chief Engineer American Air Filter Co., Inc.*

Ed.—We have no reprints of any of the individual articles, and the supply of additional copies is extremely limited. Copies of the Handbook are only available as part of a subscription to PRODUCT ENGINEERING.

To the Editor:

I feel that you are making a real contribution in this permanent record of the Engineering science. In this type of publication, engineers should have on hand for a period of time an easily available record covering many years of growth of engineering application and science.

It certainly would have been a good thing if this was started ten years ago, and perhaps it would be of some interest if you could go back some five years. —EDWARD M. GREER, *Pres. Greer Hydraulics, Inc.*

To the Editor:

It was a welcome surprise to find your Annual Handbook in the mail the other day. Since then, I have folded through your book from page to page and find that it contains interesting editorial material, as well as valuable advertising references to design components.

To illustrate my point, I found six products mentioned in the pages of your book on first examination, on which we contacted the manufacturer for further details.

—HELMUT W. SCHUMANN
Precise Products Co.

To the Editor:

I have received a copy of your Annual Handbook for 1953 and wish to express my thanks and warmest praises for the job you have done. In my opinion the Handbook will fill a long needed source of information for bridging the gap between text book theory and practical design and manufacturing processes.

The product advertising itself makes the book a gold mine of technical information to anyone confronted with the problem of obtaining pertinent data on various electrical and mechanical components which enter into a special machine or design project.

—W. H. HIMES
General Mfg. Co.

To the Editor:

I have received your so-called Handbook for 1953. To me it is nothing

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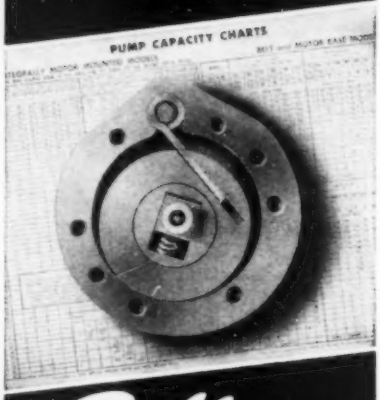

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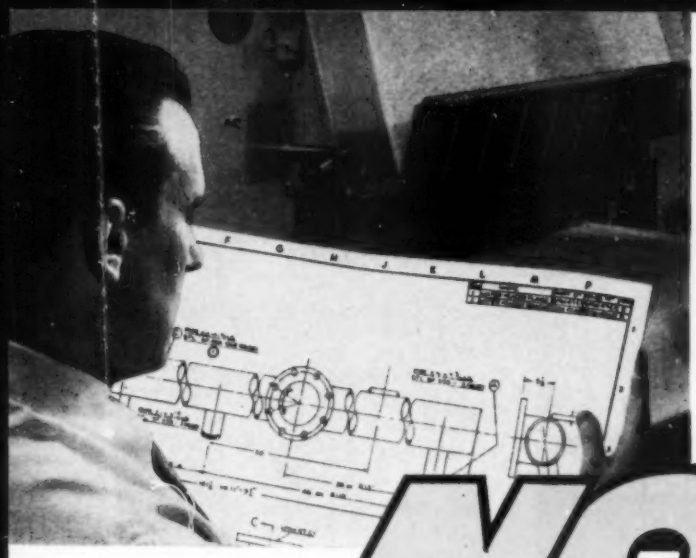

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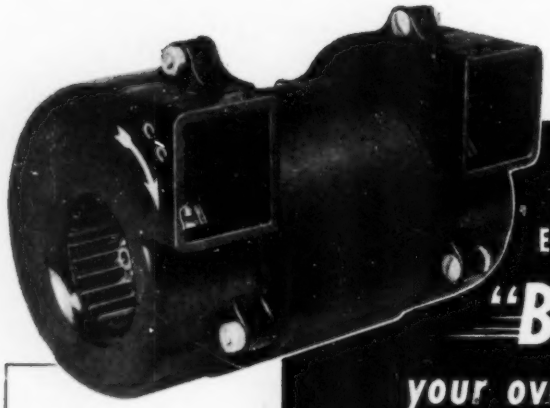

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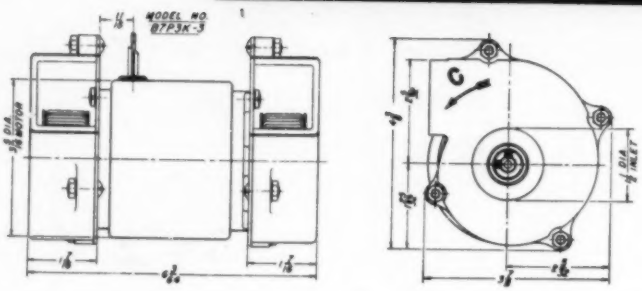
Model B7P3K-3
Frame No. 70



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more than another edition of your magazine, which will get thrown into a corner and forgotten.

My biggest disappointment, when I opened it, was to find all of those ads, destroying its value as a handbook. Unless I am mistaken, I have never seen a Handbook with ads before.

I will not bother to cut out the reference sheets, because it would entail too much work, nor will I use something that big, clumsy, and useless. —DAN BAILEY

Ed.—Advertising in the Handbook is essential. The mere mechanical production of the book, plus mailing charges were very high. Added to that were the editorial costs, the cost of the art work, and the cost of the engravings.

In selling the advertising for this Handbook our business department impressed upon the advertiser that the advertising copy should be highly factual and in data form. In other words, the advertising copy should not be merely ballyhooing the product advertised. The copy should give the reader factual engineering information. Quite a few of the advertisers followed our suggestion. We feel that the advertising pages supplemented the editorial pages in a manner that makes the book much more valuable.

Instead of cutting out the editorial pages, we thought that the readers would keep the Handbook on top in the engineering department laboratory to be of more value to the engineer in the solution of his problems.

The Wahl Factor In Spring Design

To the Editor:

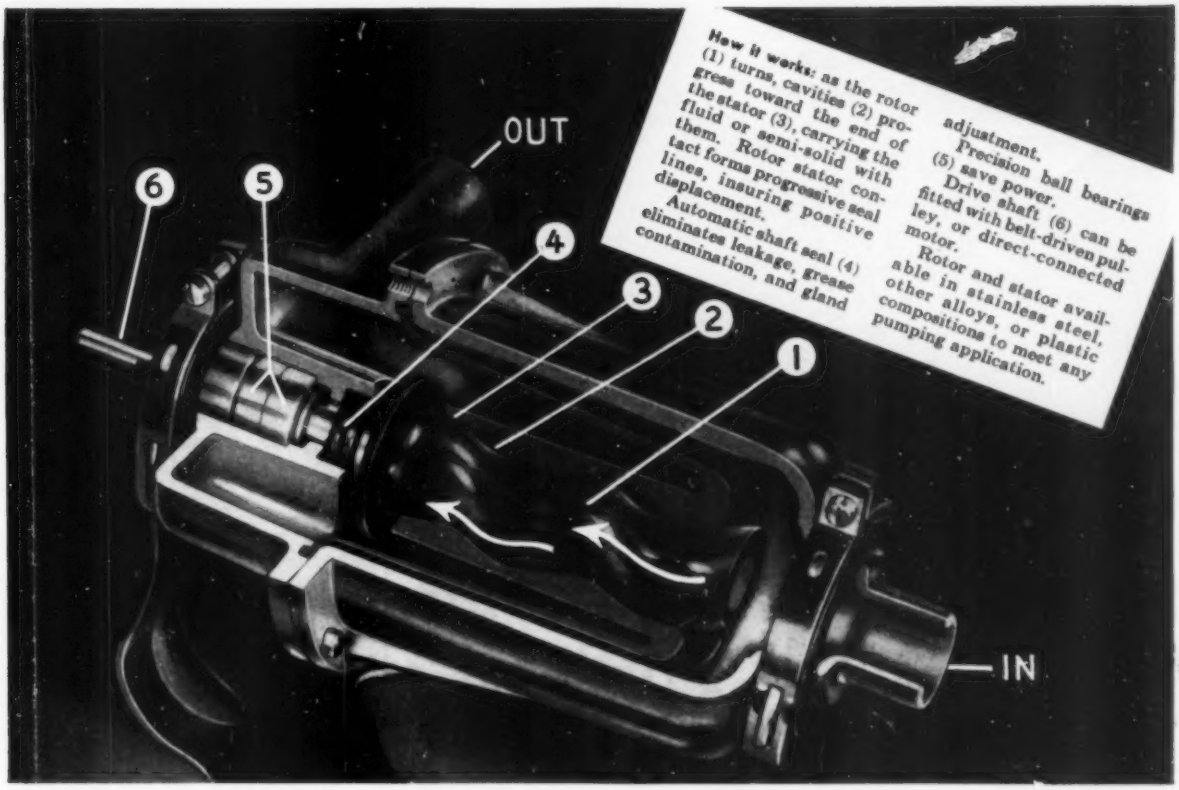
With further reference to Mr. Fradkin's letter in "Readers Say", page 294, November 1952 *Product Engineering*, last part, it might interest him to know that the Wahl factor caused by coiling the round wire is not inconsiderable. If $r=D/d$, the ratio of the mean spring diameter to wire diameter, here is how c, the percentage of stress increase varies with r:

r =	10	9	8	7	6	5	4
c =	11.5	16	19	21	25	28	40

As given by the Wahl equation:

$$C = \frac{4r-1}{4(r-1)} + \frac{0.615}{r}$$

This is awkward to introduce into the usual spring equations, but the author has evolved a close, simplified


OUT
6
5
4
3
2
1
IN
How it works: as the rotor (1) turns, cavities (2) progress toward the end of the stator (3), carrying the fluid or semi-solid with them. Rotor stator contact forms progressive seal lines, insuring positive displacement.
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Drive shaft (6) can be fitted with belt-driven pulley, or direct-connected motor.
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MONEL METAL · NI-RESIST · MEEHANITE METAL

approximation, $C = \frac{r+1}{r-0.4}$. Then, using G=11,500,000 psi, the equations for load P and deflection per turn become:

$$P = 0.393d^2S\left(\frac{r-0.4}{r(r+1)}\right) \text{ and}$$

$$= \frac{Sd^2(r-0.4)}{366 \times 10^4 (r+1)}$$

Springs vary greatly with r. For r=4, a thick springs coiling would produce 40 percent more stress. A figured comparison shows that a certain spring wound to r=4 would weigh 0.83 lb., and another spring, r=8, would weigh 0.605 lb., both with the same maximum load and deflection rate. Therefore the low r spring is uneconomical of material, but space restriction may require it.

—CARL NACHOD
Nachod & U. S. Signal Co., Inc.

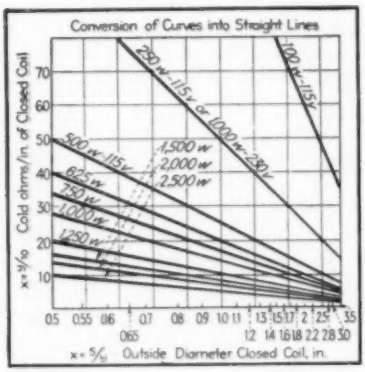
Curves On Designing Electric Heating Elements

To the Editor:

An inspection of the family of curves by Joseph Gialanella on page 207 of the October 1952 issue of *Product Engineering* shows them to be rectangular hyperbolas of the general equation $xy = c$, which is the product of the ordinates of the curve at any point. In this, c is a function of the watts marked on the curve. These values of c were taken directly from the curves themselves, since I do not have their derived equations. The table for c and r is:

r	c
100	120
250	50
500	25
625	20
750	17
1000	15
1250	10
1500	8
2000	7
2500	5

It requires considerable care and much time to plot these 10 curves carefully, and even then, they can be inaccurate. It is possible to convert each to a straight line by the method of anamorphosis or distorted coordinates. (see *Product Engineering*, December 1935, pp 459-462). By changing the scale equation of the abscissae, in this case making it an inverse scale of the equation $x = 5/y$, as shown in the figure, it has, I believe a higher accuracy and is much less



trouble to plot. Zero for x cannot be shown, since it is ∞; also, only when x is infinite can $y=o$.

The method deserves to be better known, as it is applicable to families of curves of other equations; also when a curve rises too steeply for accurate readings. —CARL P. NACHOD
Nachod & U. S. Signal Co., Inc.

Curved Extruded Plastic Parts

To the Editor:

Referring to the article "Extruded Plastic Parts" by R. S. Perkins, page 151 *Product Engineering*, October 1952, the Anchor Plastic Company holds patent 2,601,369 covering curved extrusion of such products as were mentioned.

We have successfully extruded such articles as television mounting and insulating rings for cathode-ray tubes which are used by most television set manufacturers. We have also produced circular decorative trim for other applications. —PETER H. SECKEL
Anchor Plastics Co., Inc.

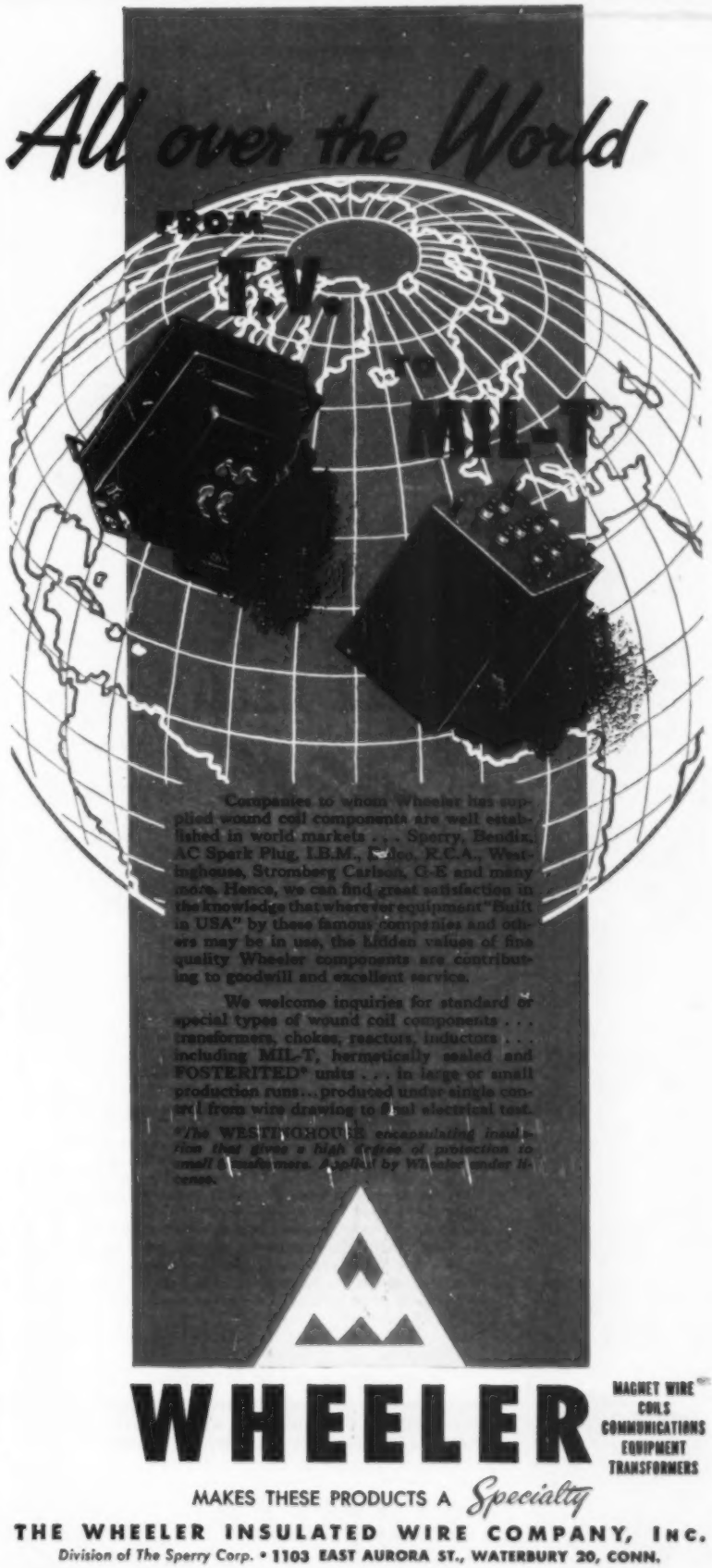
Permission to Reprint

To the Editor:

In your October 1952, issue of *Product Engineering*, the article "Using University Facilities for Industrial Research" appears on pages 185 through 189.

We find this of great interest and would appreciate your permission to reprint the article for distribution to our members only. Credit would, of course, be given.
—JEHU R. DERRICKSON
Formed Steel Tube Institute

Ed.—We are glad to extend to you permission to republish the article "Using University Facilities for Industrial Research" for distribution to your members only. In reprinting the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Wants Old Reprints

To the Editor:

I would like to purchase two copies of the article entitled "Motor Driven Machines" published in the March 1948 issue of *Product Engineering*.

—PAUL J. DEMET
Twin Disc Clutch Co.

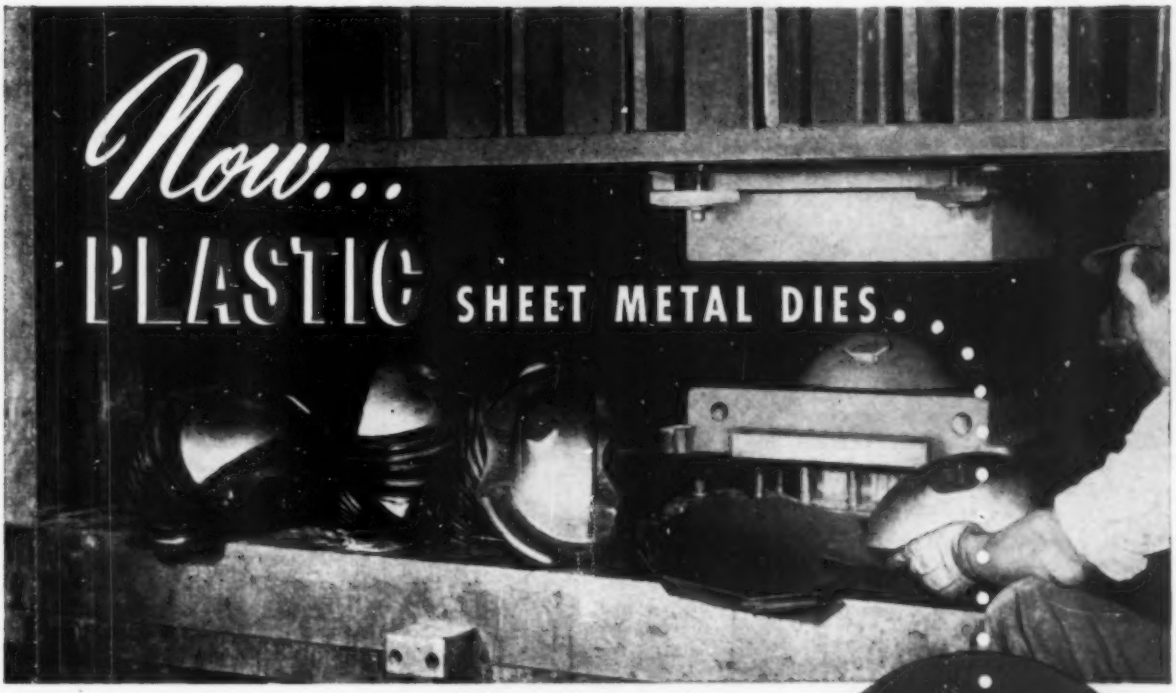
Ed.—Believe me if we could lay our hands on any copies of "Motor Driven Machines" we would certainly be glad to forward them to you. We have been out of prints on that particular insert now for nearly three years and know of no way that we could get a copy for you. Our only copy in the office is in the bound volume for 1948. We would be glad to photostat that for you, but it would cost quite a bit of money.

ERRATA

September 1952, page 202. *Strain History Determines Low Temperature Properties of Ingot Iron.* Paragraph 2, line 3.—"Minus 250 F" should be "minus 320 F." Paragraph 5, line 2—"removes some of the brittleness" should read "removes some of the low-temperature brittleness." Paragraph 7, line 3—"minus 250 F" should read "minus 320 F." Figure on page 203—"minus 78 F" should read "plus 78 F."

September 1952, gatefold opposite page 182, *High Speed Photography in Design.* Color code at top should be reversed. Opposite black line it should read, "Optical components optional in the type of camera illustrated;" opposite red line it should read, "Optical components essential in the type of camera illustrated."

In Our Readers Say Column of the October 1952 issue of PRODUCT ENGINEERING a request was made for more information on a new process known as hydro-forming, a method of drawing simple or intricate shapes in all kinds of sheet metal. We neglected to mention the Cincinnati Milling Machine Co., Cincinnati 9, Ohio, who also use this process. Presses are now capable of handling blank diameters up to 26 inches.



To meet the need for lowest-cost short run dies which can be produced quickly and accurately, Richard Brothers Division is now equipped to supply plastic dies.

Rezolin tool plastic material, which has proved to have good wearing qualities and stability, is being used for these dies. Because this material does not expand or shrink, dies can be made to extreme accuracy and with a minimum of final fitting and tryout. On short run production such as that illustrated—experimental flywheel housing covers of 20 gauge steel—the use of plastic dies results in definite savings both in initial cost and time required for delivery.

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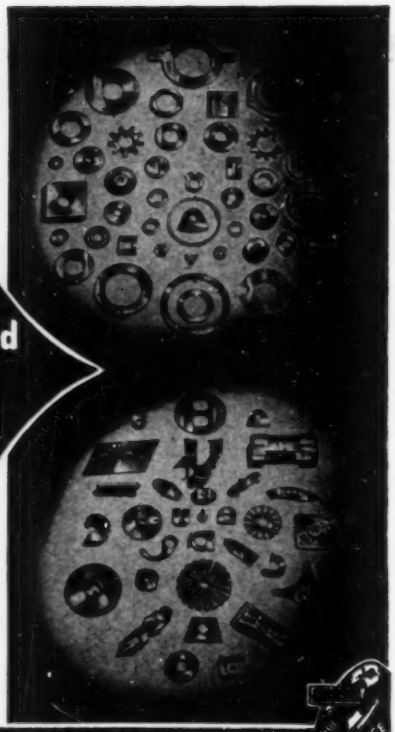

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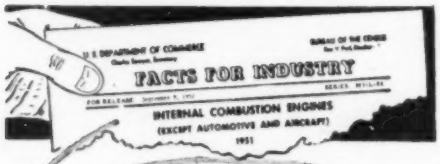
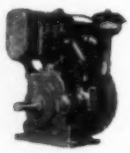


3 to 6 hp.


6 to 9 hp.

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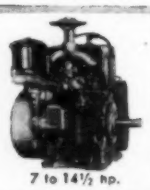
7 to 14½ hp.

15 to 36 hp.

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Based on data contained in a "Facts for Industry" report released on Sept. 5, 1952 by the U. S. Bureau of the Census, an aggregate average of 50.61% of all carburetor type internal combustion engines produced during 1950-'51 within an 11 to 175 cu. in. displ. range (approx. 3 to 40 hp.) were WISCONSIN HEAVY-DUTY AIR-COOLED ENGINES (exclusive of aircraft, automotive, outboard marine and "captive" engines built by various manufacturers for use on their own equipment).

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194 *pp.* 8x11 *in. Vickers Inc.*, 1454 *Oakman Blvd., Detroit* 32, *Mich.* $2.

This is one of a series of textbooks prepared by instructors in the Henry Ford Trade Schools for the instruction of Hydraulics. It includes information about pumps and valves and then maintenance and repair; also the practical application of hydraulics to machines for the control of speeds and feeds.

Divided into 52 lessons of from 3 to 4 pages each, it starts off with a basic discussion of hydraulics and progresses to the more complicated designs and application. Each section is well illustrated, and from 5 to 10 questions are given as homework or review at the end of each section.

Elasticity in Engineering

ERNEST E. SECHLER, *Professor of Aeronautics, California Institute of Technology.* 6 x 9 *in.*, 419 *pp. Published by John Wiley & Sons,* 440 *Fourth Ave., New York* 16, *N. Y.* $8.50.

This book has been written primarily for engineers working in the fields of structural analysis. The choice of subject matter was determined largely by the needs of aeronautical structural engineers, although it is believed that the material will be found useful for engineers in the civil and mechanical engineering fields. It attempts primarily to bring into one volume the material of most interest to the engineer who needs a broad foundation based on the fundamental theories of stress and deformation of elastic bodies under load. To this end, the first part of the book is devoted to establishing the fundamental equations and assumptions underlying the whole field of elasticity. In these chapters are collected the basic equations in Cartesian, cylindrical, and spherical coordinates which are necessary for the solution of elastic problems.

Once the basic equations have been derived, the solution of any specific structural problem can be obtained either by the rigorous application of these fundamental equations or by approximate methods of solution. The second part of this text discusses the elastic problems of stable structures

and shows where exact solutions are possible, indicates types of approximate solutions, and sets up the boundaries between which various levels of engineering accuracy are obtained. These more approximate methods are included first, to review the more commonly used beam, torsion, and truss equations and to show their limits of accuracy in terms of the more precise methods of elasticity, and second, because these more approximate equations are, at times, valuable in suggesting possible solutions to come of the more complex problems in the field. The third section deals in a similar manner with the problems of unstable elastic structures. In this way, the second purpose of the work is achieved, namely, to bring together the fields of applied mechanics, strength of materials, and theoretical elasticity. Basically, the equations derived in these fields are the same; however, the limits of validity and the restrictions on the equations are obtained only by an approach through the fundamental equations of elasticity.

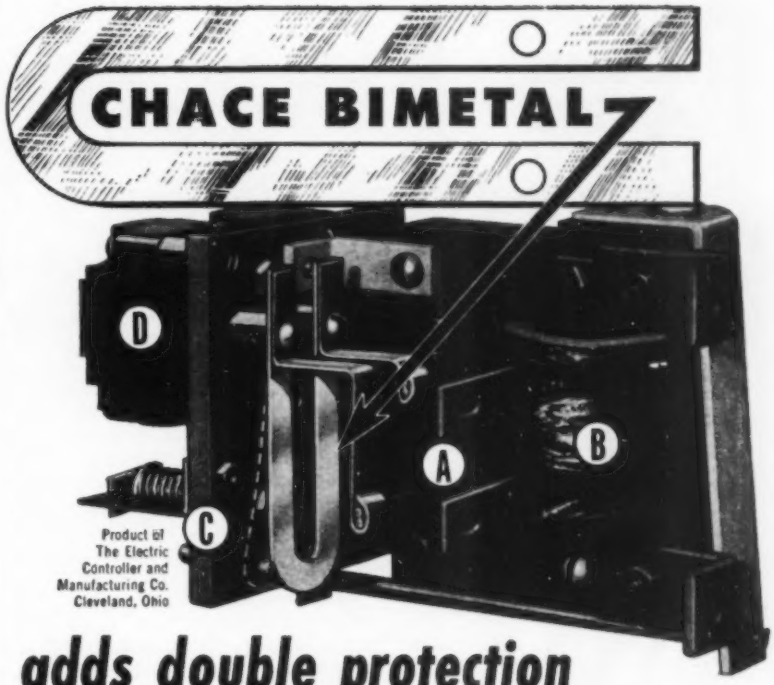
The axis notation and sign conventions have been arbitrarily assumed by the author. However, some attempt has been made to conform with the conventions normally used by the aeronautical engineer. A very definite effort has been made to keep the conventions consistent throughout the text, and for this reason care is required in correlating equations in this book with those obtained from books with different sign or axis conventions.

No claim is made by the author to originality for the fundamental ideas which are presented, since much of the material which has been included in this book has stemmed from the earlier works of Love, Timoshenko, Southwell, et al. References to these textbooks are given at the end of each chapter, and it is recommended that students interested in the background of the presentations consult these works for references to original source material.

Legal Guide for Contractors, Architects & Engineers

I. VERNON WERBIN, *Lawyer, Professional Engineer*, 374 *pp*, 6½ x 9 *in. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York* 36, *N. Y.* $4.75.

Because the author is both an experienced civil engineer and lawyer, the book thoroughly reviews and discusses 46 of the most common problems involved in the performance of



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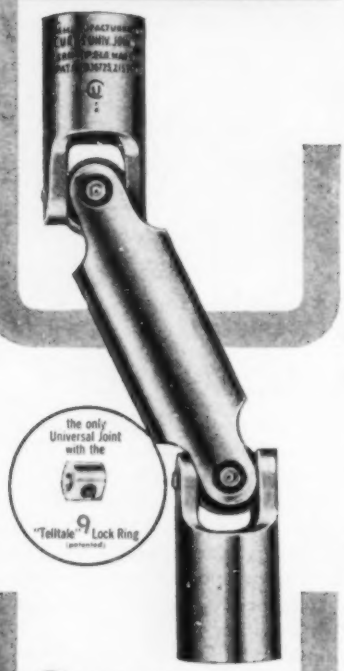

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The book is written to be easily understood by laymen as well as attorneys. It gives the facts and contract provisions involved in each situation, and cites cases to sustain the principle of law set forth.

Weight-Strength Analysis Of Aircraft Structures

F. R. SHANKLEY, *Professor, University of California at Los Angeles,* 6 x 9 *in.,* 394 *pp. Published by the McGraw-Hill Book Co.,* 330 *West* 42 *St., New York* 36, *N. Y.* $8.50.

This volume meets the need for scientifically sound methods of analyzing and predicting the structural weight of aircraft and missiles. Part I discusses methods by which the minimum weight can be determined for any material and conditions of loading. These principles of design for minimum weight are then utilized to derive weight equations for wing and fuselage structures, the subject matter of Part II. Part III includes a number of reports prepared in the course of investigations of new materials and extreme operating conditions.

A new approach to the subject has been made through the use of the principles of optimum structural design, or design for minimum structural weight. This has permitted the structural weight equations to be derived on a sound scientific basis. As a result, the weight equations may be used to determine the overall efficiency of the structure and to predict the effect of major changes in design, materials of construction, load factors, and so forth.

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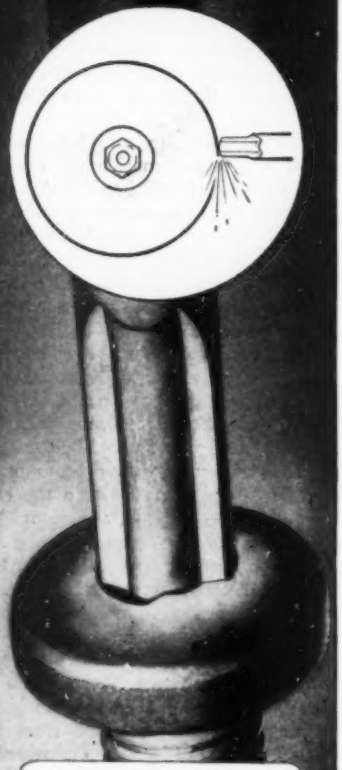

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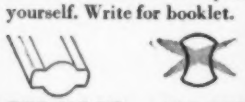

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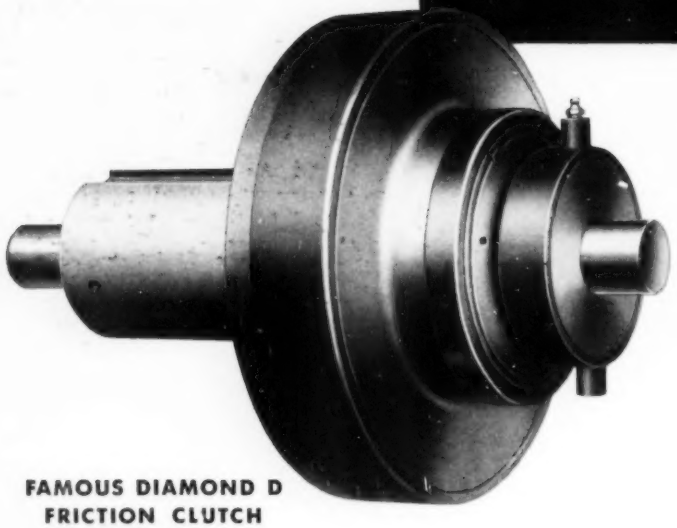

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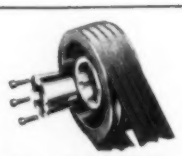

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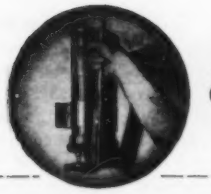

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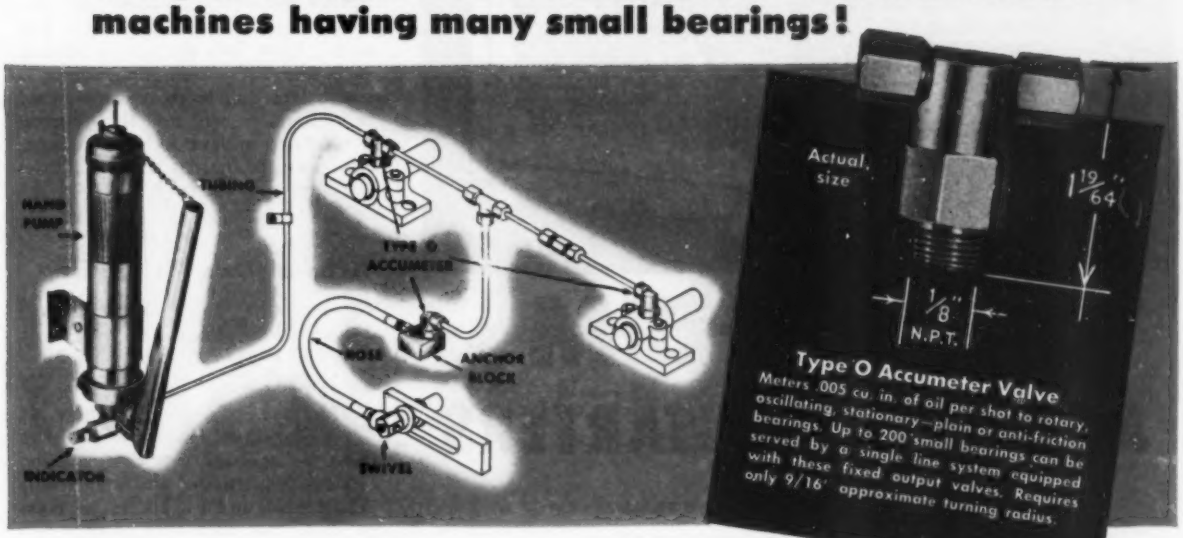
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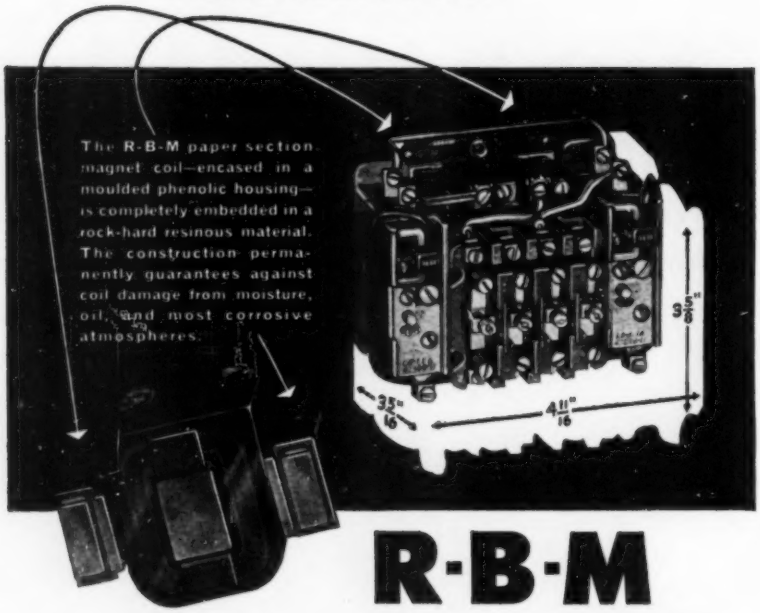
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treatment of materials have been made. One of these involves the use of integration factors which permit integration processes to be treated separately. Another new feature is the use of the structural index as a basis for determining the allowable stresses of structures which fail through instability.

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Technical Data On Plastics

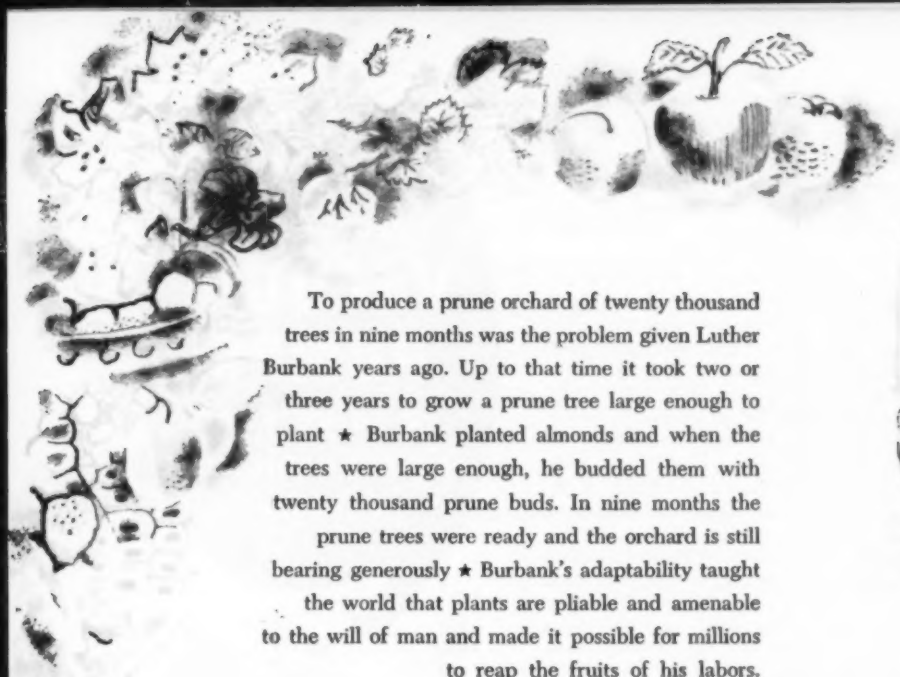
184 *pp.* 9 x 11 *in. Published by the Manufacturing Chemists Association, Inc., 246 Woodward Bldg., Washington 5, D. C.* $2.50.

This new revised 4th edition of "Technical Data On Plastics," is an industry handbook that describes and catalogs properties of all commercially available plastics. It covers 24 types of plastic materials—and contains two new sections covering the properties of various plastics in the form of foams or thin films.

This volume attempts to focus the attention of molders, fabricators of plastics on the measured properties of these materials and on the variables that affect these properties.

The materials for which data are published for the first time are alkyd and silicone molding compounds and epoxy resins. Other types of plastics covered in the book include urea-formaldehyde molding materials, melamine-formaldehyde molding materials, phenolic molding materials, cast phenolic resins, laminated thermosetting products, laminated melamine products, allyl and polyester plastics, acrylics, polyethylene, fluorocarbons, polyvinyl formal and butyral, vinyl chloride polymer and co-polymers, vinylidene chloride, cellulose acetate sheets and molding compounds, cellulose acetate butyrate, cellulose propionate, ethyl cellulose, cellulose nitrate, and nylon.

For each of the above types, the book presents descriptive information



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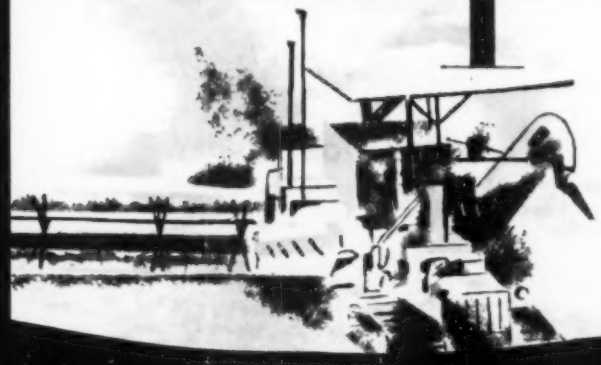

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on general characteristics; graphical and tabular data on fabrication; durability; electrical, mechanical and miscellaneous properties; typical uses, trade names and limitations.

All data contained in the volume are derived from tests made by manufacturers on their own materials. The test methods used in most cases were those established by the American Society for Testing Materials.

Sponsored by a group of MCA companies interested in plastics, the book is believed to be the most complete and authentic available as far as properties of plastics are concerned.

A study of the introductory sections, tables, the curves, and the test methods should give the user of plastics a good picture of the wide variety of properties offered by these materials as a whole and of the considerable range of compositions available in many of the individual groups.

Fatigue and Fracture of Metals—A Symposium

Edited by WILLIAM M. MURRAY, 314 *pp*, 6 x 9 *in. Published by the Technology Press, M.I.T. and John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y.* $6.

This book is a compilation of fourteen papers on the subjects of fatigue and fracture of metals presented in June 1950 at the Massachusetts Institute of Technology. These papers were prepared by specialists in different aspects of fatigue and fracture and cover the following aspects:

(a) General experience with failure of metals

(b) Specific fields in which fatigue failure occurs

(c) The internal mechanisms probably involved in fatigue damage

(d) The significance of various metallurgical phenomena to fatigue

(e) The potential usefulness of different research methods to disclose more about the mechanism itself and ways of counteracting it in design

(f) The direction of future research as recommended by the contributors of the papers.

The fundamental nature of damage due to repeated loading is very complex and lack of definite information makes the prediction of safe service life of designs practically impossible without expensive full scale testing to destruction. This volume has contributed effectively to the improvement of the control of the basic elements involved in the problem of fatigue and fracture through a survey of exist-

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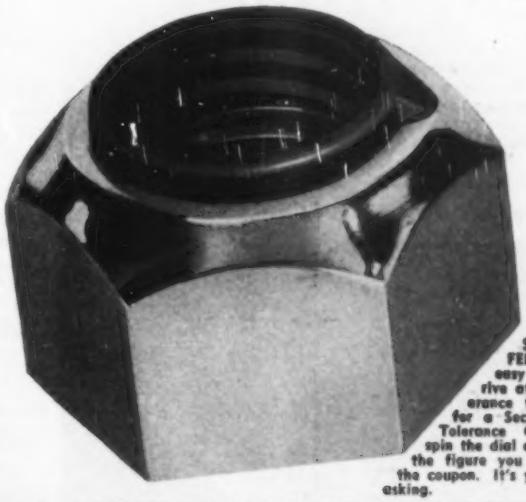

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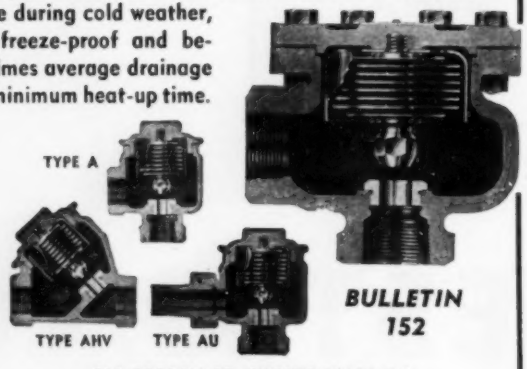

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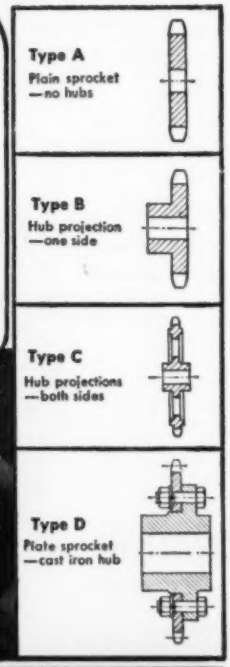

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Comprehensive papers covering the Fatigue Problem of Airplane Structures, Brittle Fracture and Fatigue in Ships and Brittle Fracture and Fatigue in Machinery give a clear insight into the practical problems experienced with dynamic loads in three outstanding engineering fields. In the aircraft industry especially, because of the gains in performance to be achieved through weight reduction, the structural engineer has pressed for more exact information on loads encountered in flight, the relation between loads and stresses in complex structures, the instability of structural elements stressed within the plastic range as well as the elastic range and the properties of materials.

The drive for weight and cost savings in other industries has also inspired concerted effort to more fully understand the causes of failures. The large number of failures caused by fatigue warrant a thorough study of all the aspects of this phenomenon. The up-to-date information presented in this book will serve as a good guide to designers in designing safe structures and machines of better performance and longer service life.

Commercial and Industrial Refrigeration

C. WESLEY NELSON, *Head, Steam and Diesel Engineering Dept., Wentworth Institute,* 6 x 9 *in.,* 467 *pp. Published by McGraw-Hill Co.,* 330 *W.* 42 *St., New York* 36, *N. Y.* $7.

Divided essentially into three parts, this book deals with elementary theory of refrigeration, classification and description of equipment, and installation and serving. The theory and principles presented are general enough to apply to the more common types of refrigeration, while the descriptive matter becomes more particular.

The author has avoided extreme fine points, but at the same time includes all necessary detail, in order that the volume may be used for either classroom or home study.

To widen the scope there are included three chapters on air conditioning—fundamentals, equipment, and installation and service.

In addition to the usual basic materials covered in refrigeration texts, the author has added several new features: a chapter on AC and DC motors used in the industry, including trouble shooting, repair suggestions, wiring diagrams, and protective de-

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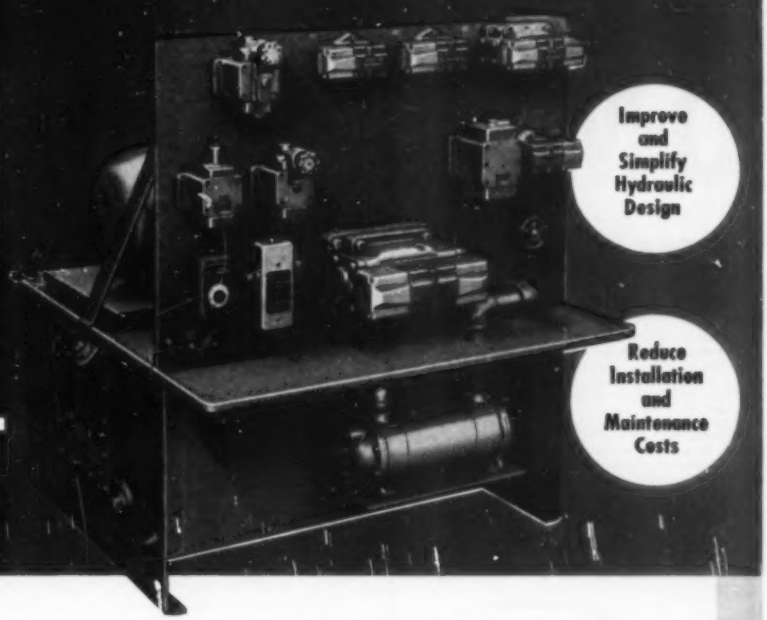

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vices; low-temperature refrigeration discussions with methods of automatic defrosting; load calculations and selection of equipment from manufacturers' catalogs with tables and data; and installation and service procedures with simple and clear diagrams which facilitate the operations.

Practical application of principles is stressed, but the fundamentals first presented allow the reader to apply his knowledge and familiarize himself with refrigeration terminology.

Advanced Mechanics of Materials

F. B. SEELY, *Prof. Emeritus of Theoretical and Applied Mechanics* and J. O. SMITH, *Prof. of Theoretical and Applied Mechanics, University of Illinois, 6 x 9 in., 680 pp. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y.*, $8.50.

Many important contributions have been made to the subject of mechanics of materials since the first edition of this book appeared twenty years ago. As a consequence, the treatment in this second edition has been made more penetrating and comprehensive, and much new material has been added. In fact, it is essentially a new book, although the main objectives are the same as in the first edition.

Although methods of analysis are given careful attention throughout, equal emphasis is given to the engineering evaluation and interpretation of the analyses as influenced by the assumptions made and principles used.

The book was prepared primarily for advanced undergraduate and first-year graduate students in engineering, but in selecting the topics and methods of presentation the needs of design and research engineers were kept in mind.

Where differential equations are involved in the analysis, their solutions are obtained and the results, for a rather wide range of conditions, frequently are presented in the form of tables or curves. Numerical methods which are usually effective in the solution of differential equations for some combinations of physical conditions encountered in the analyses of this subject are not emphasized in this book.

The treatment consists of six parts. Part I includes such basic topics as elementary stress formulas for static loads, stresses and strain at a point and theories of failure by yielding. Part II treats some special topics like unsymmetrical bending, curved flexural

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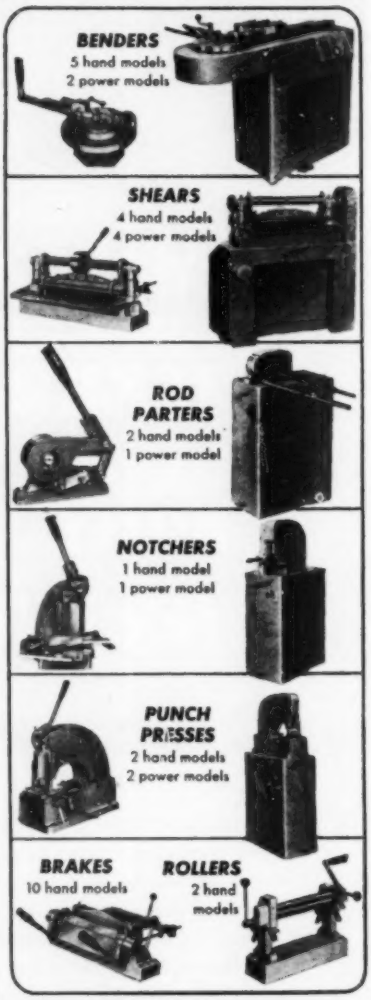

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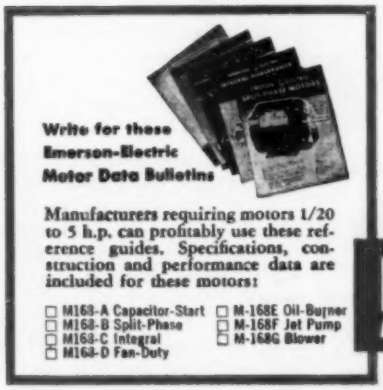

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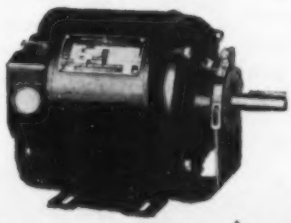

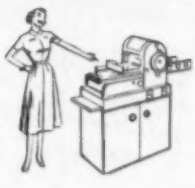

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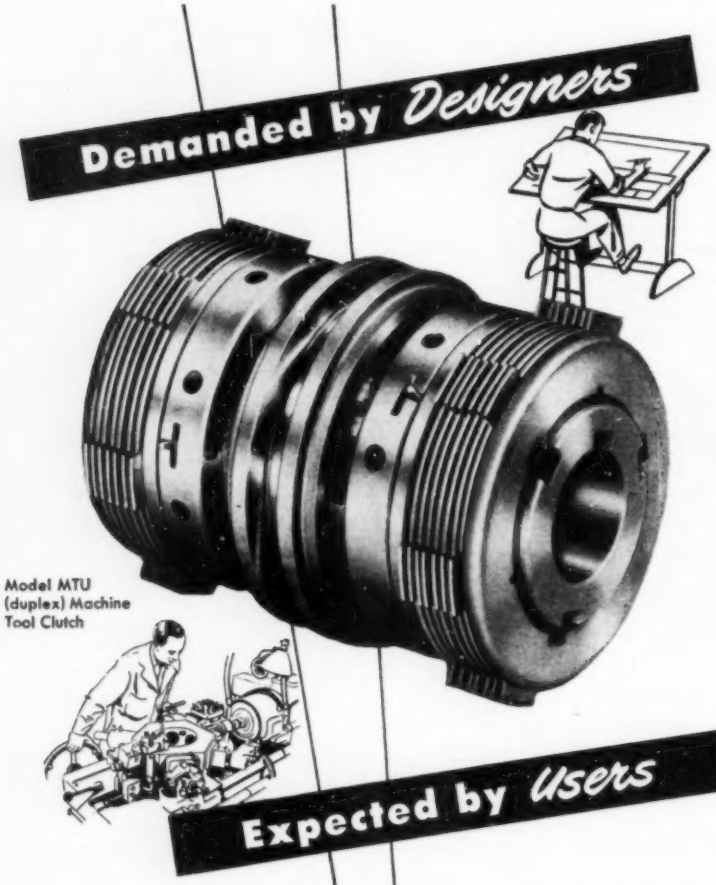

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members, beams on continuous elastic supports, flat plates, non-circular bars, thick-walled cylinders and contact stresses.

Part III discussed localized stress and stress concentration, both theoretically and as determined by experimental techniques. Part IV covers energy methods. It includes considerations of energy principles for determining relations between loads and deflections, applications of Castigliano's theorem, and deflections of members and simple structures by the unit load or dummy load method.

The fifth part considers the influence of small elastic strains on the load carrying capacity of members and the last part is an introduction to the elastic and inelastic buckling of columns and tubes. These last two sections are new. Likewise, two new appendices have been added.

The purpose of the first appendix is to give the reader, who is not familiar with the methods employed in the theory of elasticity, an opportunity to compare this method of analysis with that used in the so-called method of mechanics of materials as emphasized by the author. In treating certain topics in the method of analysis the results of the mathematical theory of elasticity supplement the method of mechanics of materials. And, since it is assumed that students and engineers who have not had a formal course in the theory of elasticity may wish to make use of the treatment of these topics, Appendix I should serve a useful purpose. In like manner the addition of Appendix II, The Elastic Membrane (Soap-film) Analogy for Torsion, which makes use of the method discussed in Appendix I, should be helpful to the reader who wishes to understand the mathematical basis of the analogy.

Automation

JOHN DIEBOLD, *Management Consultant, Griffenhagen & Associates,* 6 x 9 *in.,* 181 *pp. Published by D. Van Nostrand, Inc.,* 250 *Fourth Ave., New York* 3, *N. Y.,* $3.

Although intended for popular consumption, this book should prove particularly interesting to nearly all engineers. It is a provocative study of the possibilities, limitations and social and economic effects of the new machines of the electronic era. Such factors as what they mean in terms of jobs, cost of goods and services, standards of living and increased leisure time are considered.

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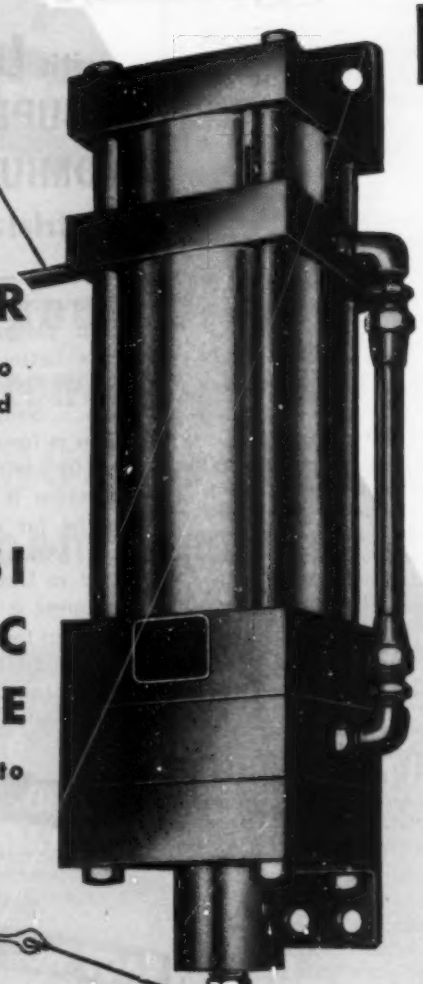

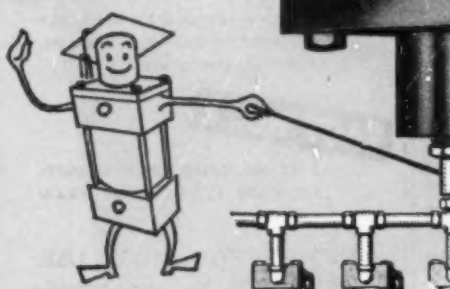

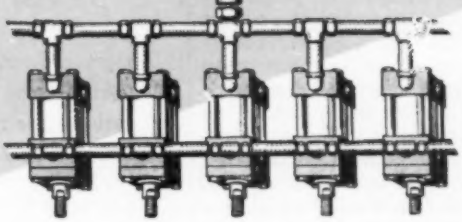

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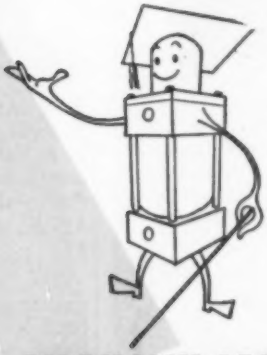

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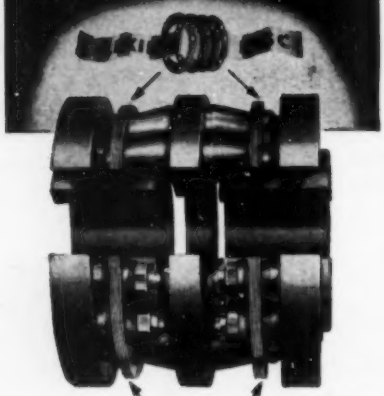

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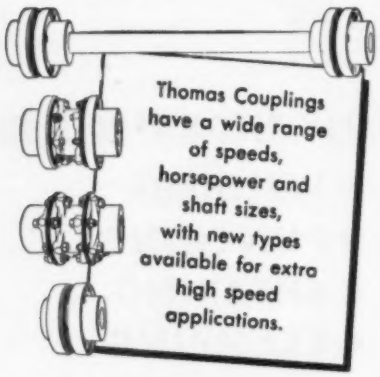

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Statistical Theory in Research

R. L. ANDERSON, *Prof. Institute of Statistics, University of N. C., and* T. A. BANCROFT, *Dir., Statistical Lab., Iowa State College.* 6 x 9 *in.,* 399 *pp. Published by McGraw-Hill Book Co.,* 330 *W.* 42 *St., New York* 36, *N. Y.,* $7.

This is a combined textbook in mathematical statistics and a reference book for the research worker. It is divided into two parts. Part I presents basic statistical theory, including the elementary principles of probability, population and sampling theory with moment-generating functions, orthogonal linear forms, and the theory of estimation and tests of significance. A chapter on the theory behind the use of chi-square is included. An attempt has been made to minimize the number of mathematical methods and theorems used in developing the statistical methodology. Material is organized according to specification, distribution, estimation and tests of hypotheses.

Part II presents the theory of least squares and its use in the analysis of actual experimental data, including multiple regression, experimental design, and variance component models. In both parts the theory is always illustrated by several examples, and many exercises are provided.

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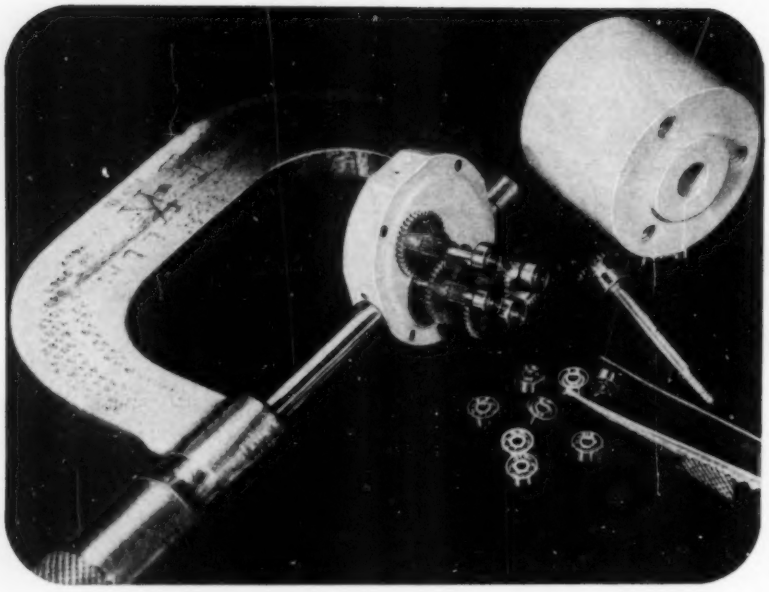

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been kept to a minimum in order that the reader may come to grips with the development of fundamental statistical methodology per se as quickly as possible.

Orthogonal linear functions are introduced in Part I and used in proofs in sampling distribution theory instead of the customary classical methods. These functions are also needed in the author's approach to least squares problems in Part II.

The large amount of actual experimental data used to illustrate the theory is a feature of the text.

Statistical Tables And Problems

ALBERT E. WAUGH, *Prof. of Economics, University of Conn*, 6 x 9 *in.*, 242 *pp. Published by McGraw-Hill Book Co.*, 330 *W.* 42 *St., New York* 36, *N. Y.*, $5.50.

With the complications of today's statistical methods, the statistician finds it impossible to operate in practice without a laboratory manual giving the most-used tables and collecting the common formulas.

This is such a manual. Designed to fill the needs of student and professional statistician, it includes all the common tables carefully arranged for the purpose of facilitating work in long problems.

Besides the common tables, there are included tables giving areas and ordinates of skewed curves, tables *t*, *F*, and *z*, tables of the Poisson function, tables of chi-square, and a short table of random sampling numbers. It is designed to be used in conjunction with a standard text on the subject

Engineering Materials

MELVIN NORD, *Dr. Eng. Sci., LL.B., Assoc. Prof. of Chemical Eng., Wayne Univ.*, 6 x 9 *in.*, 518 *pp. Published by John Wiley & Sons, Inc.*, 440 *Fourth Ave., New York* 16, *N. Y.*, $6.50.

This book is intended specifically to be a textbook for all engineering students at approximately the sophomore level. Therefore, its presentation is basic—a major aim of the author is to organize the scattered information on engineering materials into a coordinated study.

The first half of the presentation is a general treatment of the subject. Beginning at an elementary level, it introduces fundamental concepts in physics, chemistry, geology, and other basic subjects. Practical problems of

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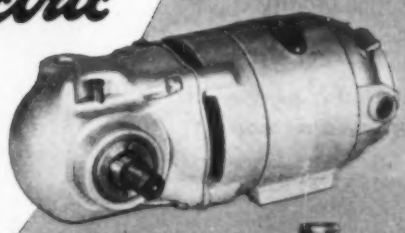

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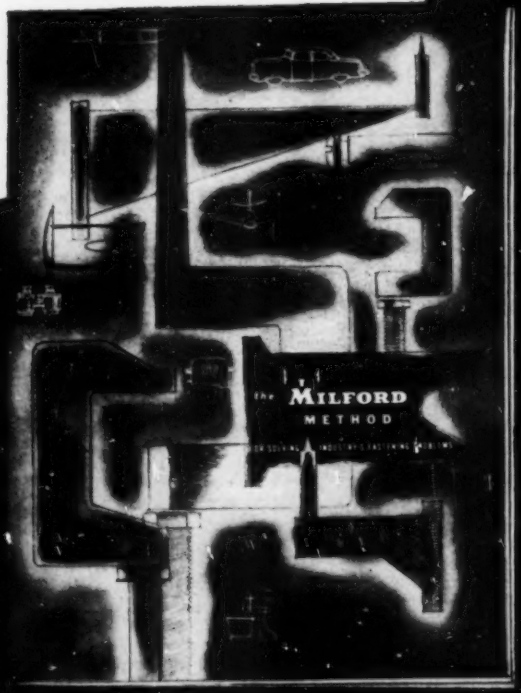

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importance are solved in each of the various branches of engineering. Here the scattered information about engineering materials is gathered and interpreted. The raw materials of engineering, the manufacture of engineering materials from the raw materials, and the properties of engineering materials are all studied in a general way.

In the second half the specific materials of engineering are treated in the light of the generalizations made. The basic engineering concepts introduced in the first half are applied to problems of occurrence, problems of production, problems of properties, and the uses of various engineering materials. This treatment of the subject matter shows how to apply simple concepts in science to engineering, and how economic factors affect engineering practice.

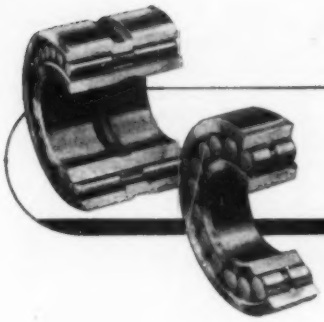
Encyclopedia of Surface-Active Agents

J. P. SISLEY, *Gen. Dir., Technical Institute of Studies & Research, General Secretary, Assoc. of Chemists of Textile Industry (both in France). Translated and revised by* P. J. WOOD, *Tech. Dir., Royce Chemical Co., 6 x 9 in. Published by Chemical Publishing Co., 212 Fifth Ave., New York, N. Y., $15.*

Part I deals with the general aspects of surface-active agents, their properties, applications and methods of manufacture. It also gives a system of classification by which every variety of the modern surface-active agents can be identified by simple symbols.

Among the chemicals covered are wetting agents, detergents, penetrants, foaming compounds, emulsifiers, and dispersing agents. The book takes an inventory of all the sulfonated oils and modern detergents currently manufactured. It groups them into main and subclasses according to their chemical compositions. It describes their many applications in the textile industry; leather industry; as industrial and household detergents; in the treatment of metals; in surface coatings; in paper manufacture; as flotation reagents; for the breaking of emulsions; in fat splitting; in soap making; in the rubber industry; in fruit and vegetable processing; in cosmetics; in inks; in cutting and soluable oils.

Part II is a compilation of data on all major commercially available surface-active agents which have appeared on the world market. For easy reference, these products are arranged in alphabetical order of their brand name. For most of the items the following



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Capacities at 2500 hours average life at 100 RPM

long life, versatility of mounting, and ease of lubrication. Published ratings show the Guiderol CT Series bearing has over 33% greater load carrying capacity than the average of the four highest rated interchangeable bearings. As a result, a Guiderol bearing at least one size smaller can often be substituted with the necessary shaft and housing requirements reduced in size and cost.

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In the Guiderol bearing design the grooved rollers with full race width contact are prevented from skewing by a center guide rail. Normally the rollers run on a true axis

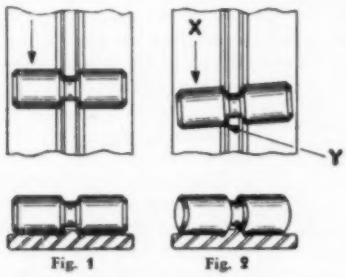
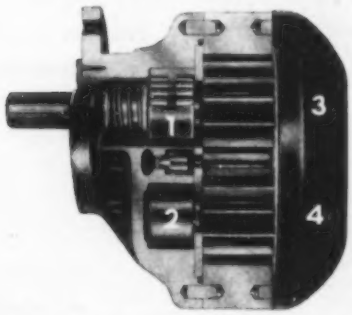


Fig. 1 Fig. 2

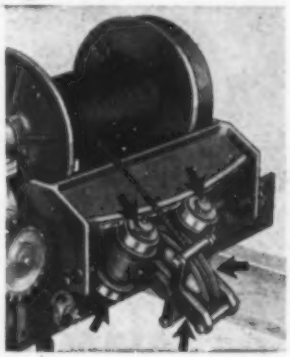
— not contacting the rail and thus need no correcting. (Fig. 1) Should misalignment cause a shift off center (Fig. 2) the leading end of the roller is retarded by contact with the rail at location Y. The trailing end catches up, relieving the rail contact, and the roller then resumes normal operation.

Typical GUIDEROL® Bearing Mountings

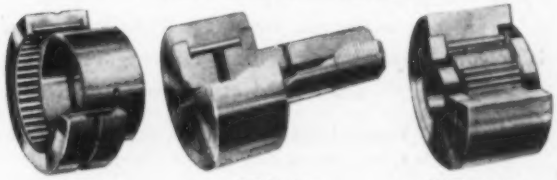


On a Hydreco Gear Pump Idler and Drive Shaft, 4 Guiderol bearings are used. The longer rollers of the Guiderol bearings are effective virtually to the edge of the races. This gives substantial support close to the gear and materially reduces shaft deflection.

Four Guiderol bearings support and guide an automatic spooling attachment across the face of the reel track on a 20,000 pound Gar Wood Reel-Lite Winch. The guided roller principle prevents skewing of rollers in the 4 vertically mounted bearings even with a 10,000 pound angular load per bearing. A fifth Guiderol bearing in the sheave provides added stability and eliminates binding due to off-center loading.



MULTIROL® Bearings



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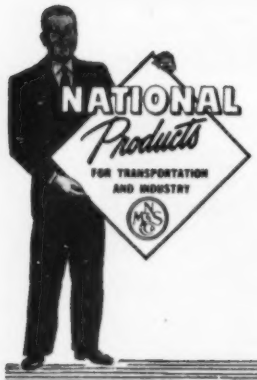

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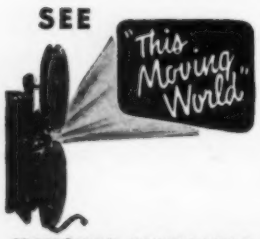

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Investment Castings For Engineers

R. L. Wood and D. Von Ludwig, *6 x 9 in., 477 pp. Published by Rheinhold Publishing Co., 330 West 42 St., New York 36, N. Y., $10.*

This volume presents a comprehensive description of the important features and the advantages and disadvantages of investment castings as they are now used in industry.

Emphasis is placed upon the design engineering factors that govern the attainable accuracy of dimensions and the metallurgical advantages of precision cast products. This book defines clearly what can actually be accomplished by the commercial modifications of the "lost wax" process. Recent techniques, such as the frozen mercury and ceramic shell mold processes, are described in detail. Various inter-relationships between these processes are clearly defined.

Full chapters are devoted to product design development by investment casting, suggestions for replacing fabricated parts and techniques for machining precision castings.

Design and Use of Cutting Tools

Leo J. St. Clair, *Cutting Tool Consultant. 421 pp. 6¾ x 9½ in. Published By McGraw-Hill Book Co., 330 W. 42nd St., New York 36, N. Y. $7.*

A highly practical treatment of the many problems involved in selecting, designing, grinding, and using machine cutting tools. The book is written in shopman language, and shows how to use cutting tools more efficiently and economically while turning out better work.

Functions of the various tool angles —side and end relief, angle of clearance, side and back rack—are treated in detail to aid in the design of better tools. Good and poor qualities of different tool materials are outlined. Chip formation and chip control, and ways of maintaining an efficient cutting edge are thoroughly discussed. There is also considerable material on grinding tools, and selecting the best cutting speeds and feeds plus ideas for increasing tool life and hints for strengthening the cutting edges of tools.

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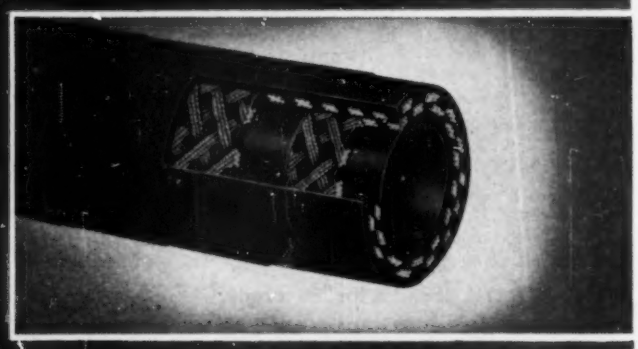

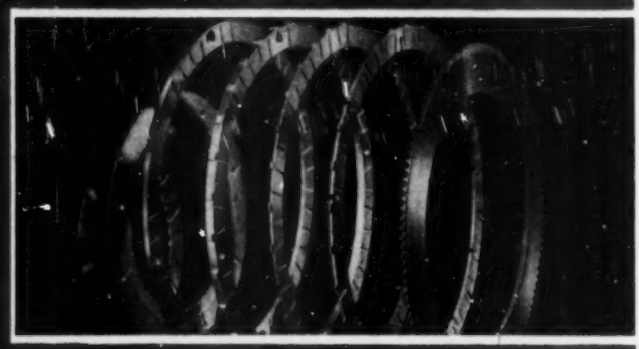

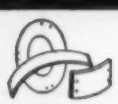
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"The 'Flying Typewriter' and all electronic counters require electric components that are rugged and reliable"

says Jack Leight, Sales Engineer,
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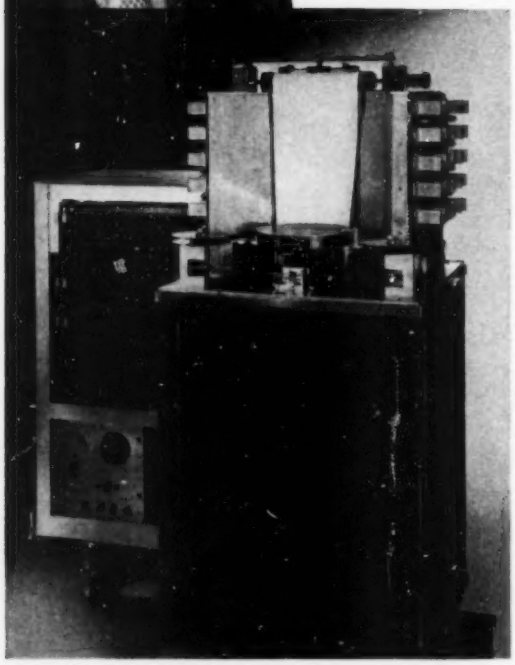

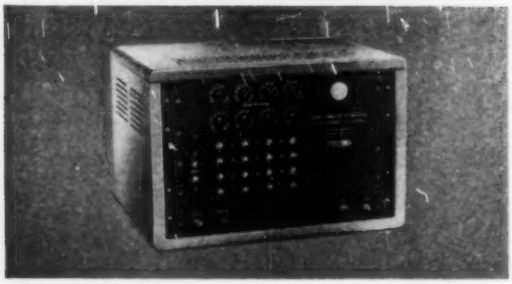

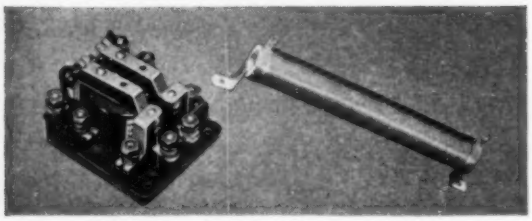

The "Flying Typewriter" is a revolutionary new high-speed electronic printer for data handling, communications, and computing. Developed by the Potter Instrument Company, Inc., Great Neck, New York, it is capable of printing 24,000 characters a minute "on the fly" from a continuously revolving type wheel.

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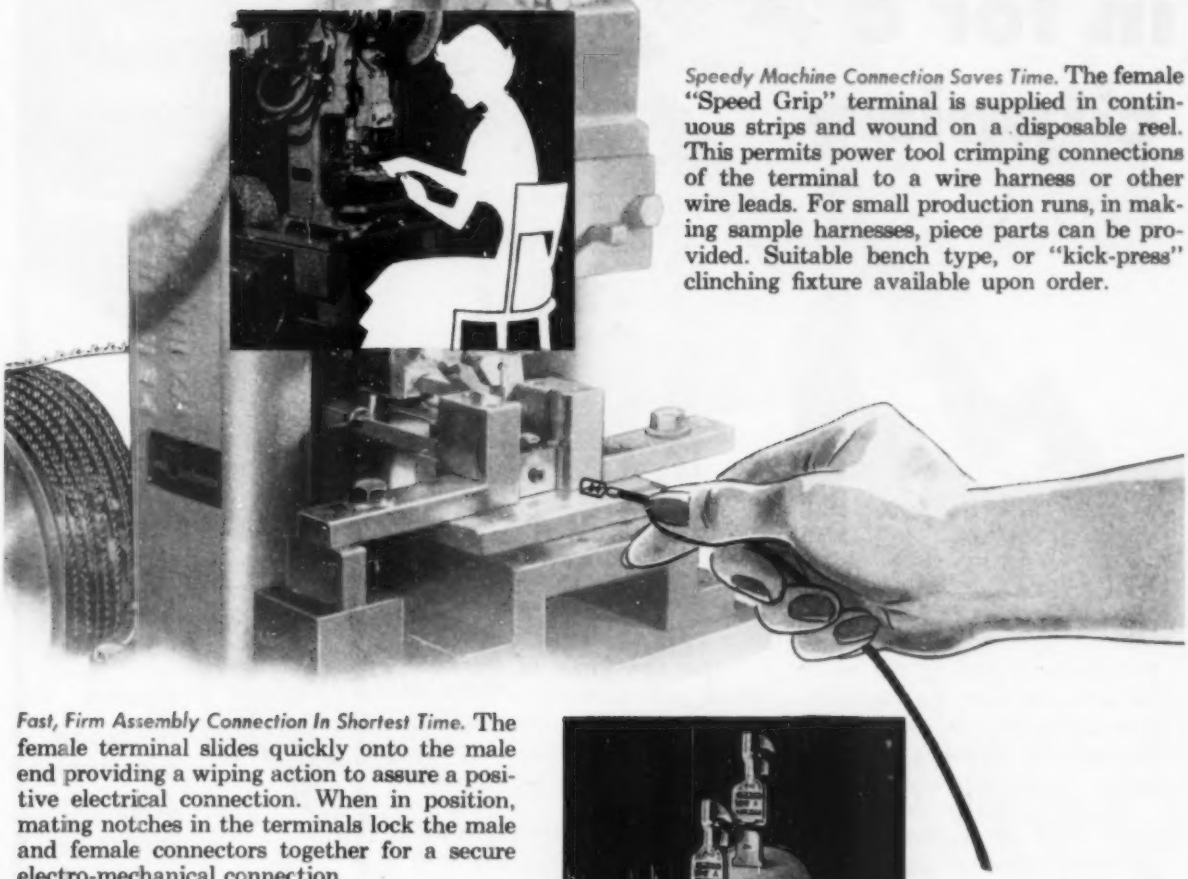

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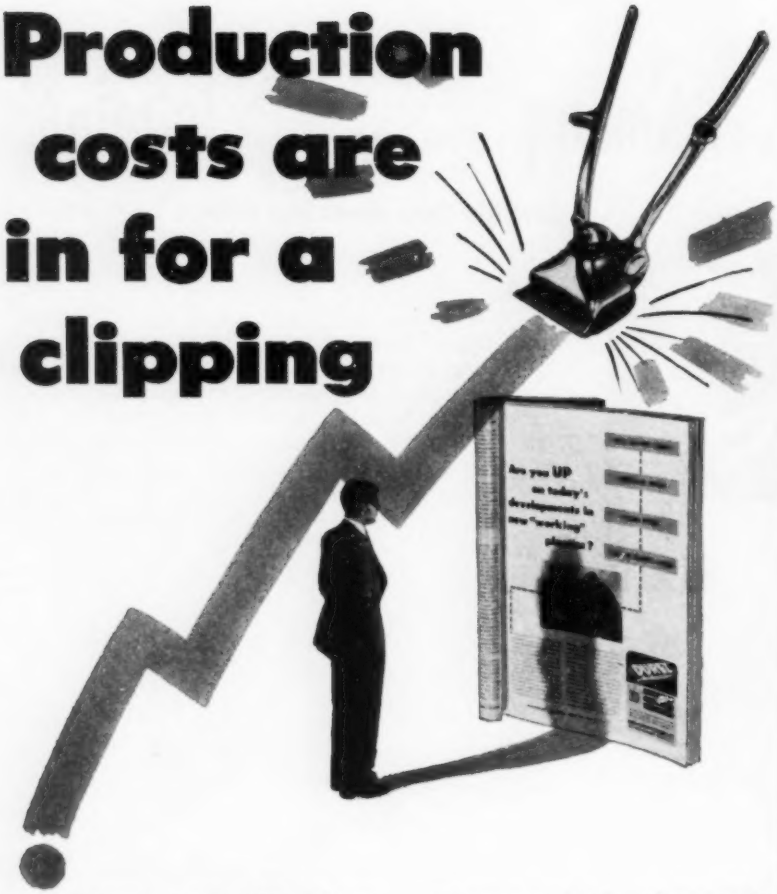

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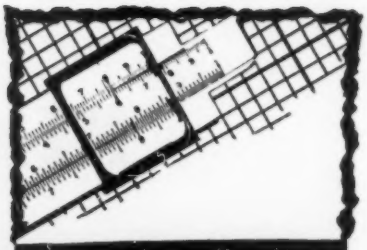

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Choose SMITHway V. H. S. motors for

POWER TO SPARE

SMITHway Vertical Hollow-shaft Motors have *reserve power* which enables them to carry sustained overloads without injurious overheating This is just *one* of the *many* reasons why they're the choice of users in every category – private, corporate and municipal, where water supply must be dependable and delivery must be at lowest cost per gallon. For complete information, see nearest office or write for latest bulletins.

OUTSTANDING FEATURES: Rugged cast iron frames and end bells. Weather proof, protected construction. Precision machined throughout. Moisture resistant insulation. Pressure cast, dynamically balanced rotors. Dual balanced ventilation. Sealed bearing enclosures. Metered oil flow. Easy to service. Many other features. Wide range of ratings from 1 to 500 H.P. SMITHway Vertical Motors also available in Solid Shaft Design over the same range.

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ELECTRIC MOTORS

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1000 Webster St., Dayton 4, Ohio • Offices in Principal Cities • International Division, Milwaukee 1

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SERIES "N" HYDRAULIC CYLINDERS

- Long recognized as the finest hydraulic cylinder made.
- No tie rods; ideal for long-stroke applications
- 12 bore sizes, 1" to 8"
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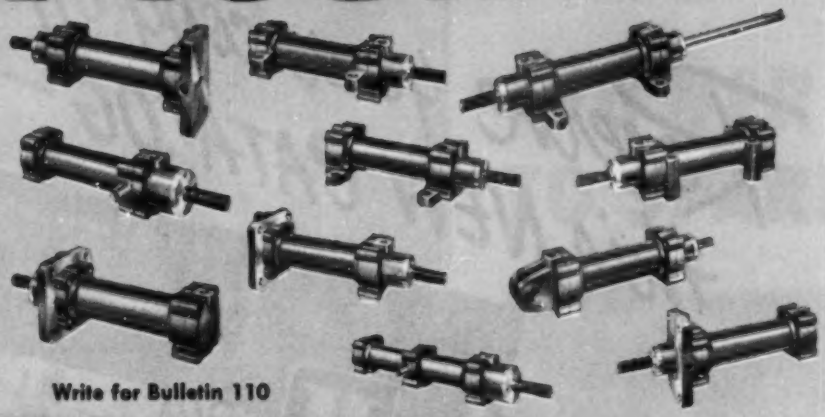

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New HANNIFIN "Space Saver" HYDRAULIC CYLINDERS

- Here is a square-type cylinder built to Hannifin's exacting standards
- Especially designed to meet the needs of machine tool builders

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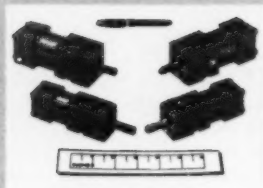
Series SS—9 Bore Sizes, 1½" to 6" Four popular mounting styles, rugged construction, for pressures to 2,000 p.s.i.



Type U—Pressures to 1000 P.S.I. 1", 1¼", 1½" Bores—Ideal for jig and fixture work. Write for Bulletin 112

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- Built in quantity for use on customers' products
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ORTMAN-MILLER SAYS . . .

WARPAGE AND BENDING ELIMINATED

MACHINING SPEED INCREASED 20%

WITH GROUND AND POLISHED

STRESSPROOF®

SEVERELY COLD-WORKED, FURNACE-TREATED STEEL BARS

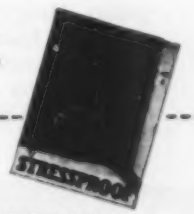
This piston rod, made by Ortman-Miller Machine Co., Hammond, Ind., for their hydraulic cylinders, is machined from Ground and Polished STRESSPROOF.

When this piston rod was made from C1018, Ortman-Miller had trouble with warpage after machining, and with bending and wear in operation. By switching to Ground and Polished STRESSPROOF, warpage was eliminated and machining speed increased 20%. In addition, STRESSPROOF had the strength to prevent bending, and wear became no problem.

STRESSPROOF has improved quality and lowered costs in hundreds of similar applications because of its unique combination of four qualities in-the-bar: (1) *High Strength*, double that of ordinary cold-finished shafting; (2) *Machinability*, fully 50% better than heat-treated alloys of the same strength; (3) *Wearability*, without case hardening; and (4) *Minimum Warpage*. STRESSPROOF is available in cold-drawn or ground and polished finish.

STRESSPROOF makes a better part at lower cost.

SEND FOR . . .
Free Engineering Bulletin
"New Economies in the Use of Steel Bars"



La Salle **STEEL CO.**

Manufacturers of the Most Complete Line of Carbon and Alloy Cold-Finished and Ground and Polished Steel Bars in America.

La Salle Steel Co.
1430 150th Street
Hammond, Indiana

Please send me your STRESSPROOF Bulletin.

Name_____

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...Highlight your product appeal

These new low cost Velvaglaze Finishes capture the gleaming brightness that highlights product appeal. They offer greater surface durability and resistance to scratching, discoloration and stain.

Many unusual finish designs are available through Monarch's exclusive Velvaglaze Process. These designs cut casting costs by eliminating multiple finishing operations. They reduce rejects now encountered on highly polished, easy to mar surfaces.

Velvaglaze Finishes offer you an additional bonus when you specify Monarch aluminum Permanent Mold Castings and aluminum Diecastings. Consult with a Monarch engineer on all of your casting and finishing requirements. He will give you complete information on the specific Monarch service that meets your individual need.

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• Aluminum Permanent Mold
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• Complete Product Assembly
• Every Modern Finishing Service
Detroit Ave. at W. 93rd St., Cleveland 2, Ohio

*T. M. Reg. U. S. Pat. Off.

gears on time

What is more important in the manufacture of gears and gear assembly than PRECISION?

Amgears carries precision a step further . . . right into their production scheduling which assures delivery on time!

Amgears gives you skilled gear men, all types of gear-making machines, metallurgical laboratories . . . facilities so complete you have the equivalent of your own gear department, plus a Production Control Department that guarantees delivery on time.

So if you are held up by delays and excuses over delivery schedules . . . or if you want to get gear production right now, phone or wire an Amgears Engineer!

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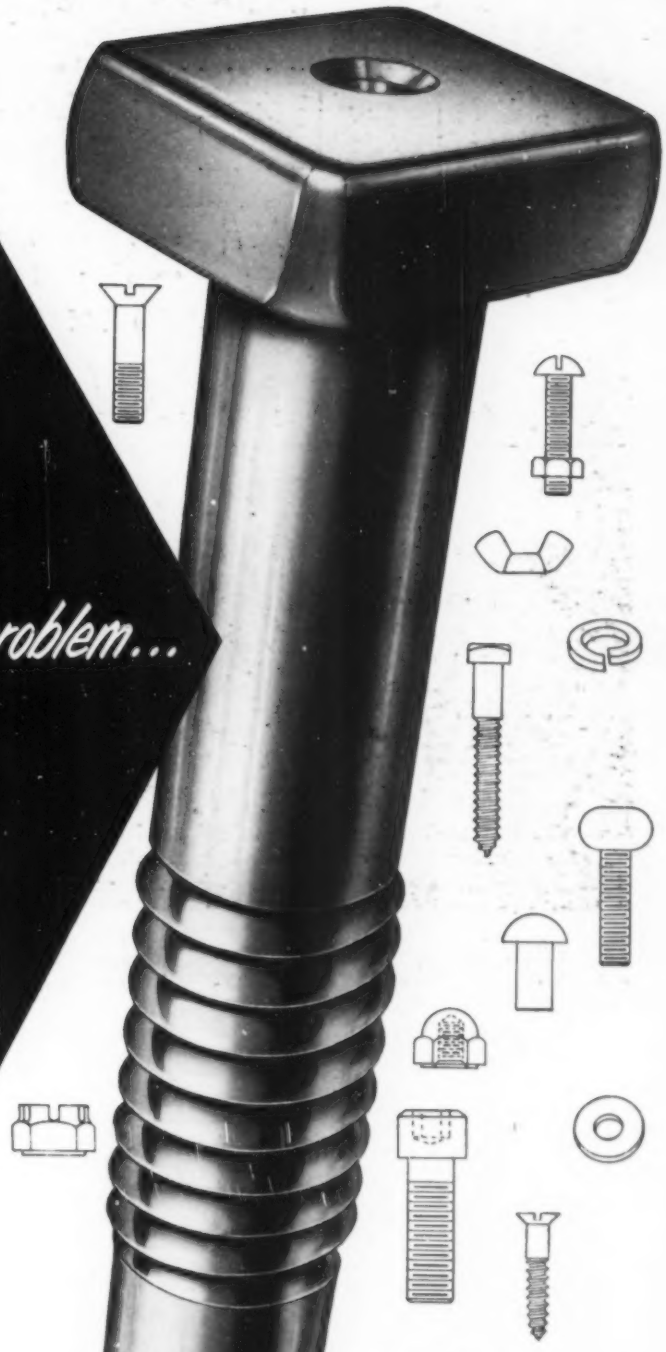
A HARPER SPECIAL...

to solve your special problem...



On the equipment you manufacture, a special fastening by Harper may improve your product—cut costs—speed assembly—or simplify maintenance.

Harper regularly produces hundreds of special type fastenings for a wide range of products. Qualified engineers and metallurgists, backed by over a quarter century of experience, are available to work with you on the design and production of fastenings engineered to your specific requirements.

The H. M. Harper Company is also the world's largest exclusive producer of standard fastenings made of non-corrosive metals and all stainless steels. Over 7,000 items are regularly carried in stock. Call the Harper Branch Office or Distributor nearest you. And remember, Harper engineers and metallurgists are eager to help you solve any tough corrosion problem.

Tap Changer Fastening of Copper Used in Transformers

THE H. M. HARPER COMPANY
8203 Lehigh Avenue, Morton Grove, Illinois

BRASS · SILICON BRONZE · NAVAL BRONZE · ALUMINUM

MONEL · ALL STAINLESS STEELS

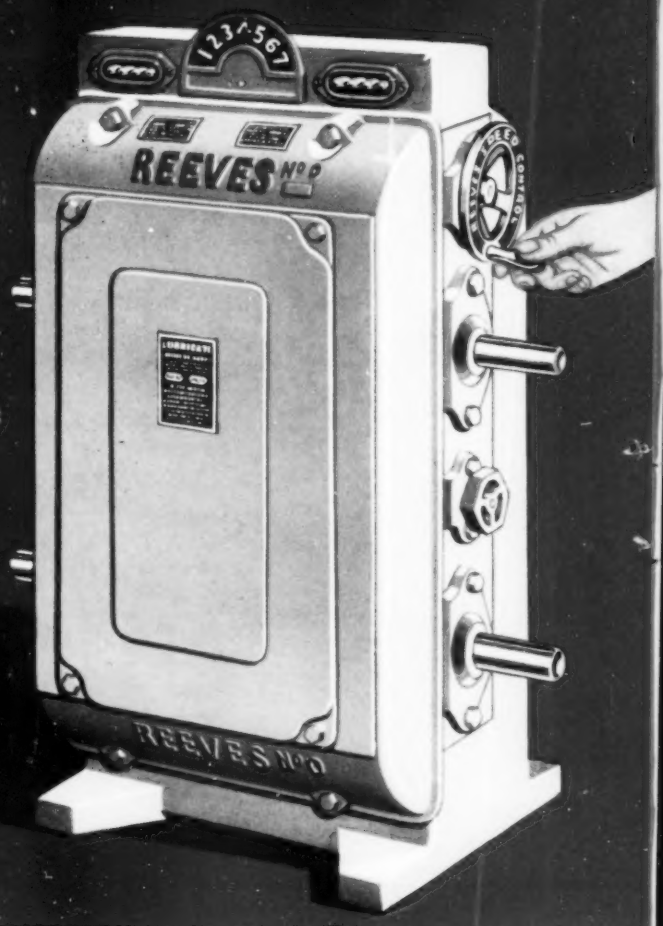
SPECIALISTS IN ALL NON-CORROSIVE METALS

HARPER

EVERLASTING FASTENINGS

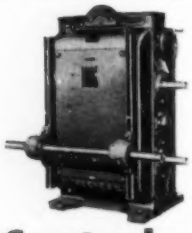
REEVES

Variable Speed Transmission*



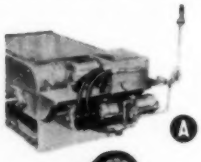
* The original, mechanically correct unit for providing complete, stepless speed adjustability.

Available in a wide choice of designs and sizes



Vertical and horizontal models, open or enclosed, with motor base, countershaft (shown at left), or integral gear reducer, where desired. "Internals"—actual speed-changing mechanism without frame or case—also available for incorporation within machine framework. All units offered in fractional to 87-hp sizes; speed ratios, 2 to 1 through 16 to 1.

Controls and indicators for every specialized need



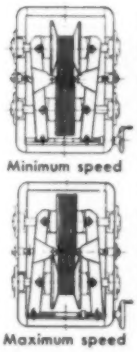
Handwheel control standard. Hydraulic automatic (A), electric tachometer (B), electric remote (C) and extended handwheel (D) are among the many controls and indicators available.

Select any speed–

accurately and positively—with the turn of a handwheel or touch of a button

REEVES Variable Speed Transmission, used more widely in more different industries than any other variable speed drive, assures *accurate, positive* delivery of any desired speed over a wide range, with the turn of a handwheel or touch of a button . . . without stopping the machine. It makes use of the machine's full production potential . . . allows it to handle more different shapes, sizes, and materials . . . utilizes the highest skill of every operator.

For higher output and improved, uniform quality of production, equip the machines you buy or build with **REEVES** Transmissions. A wide selection of designs, sizes, speed ratios, and controls assures the right installation for every need . . . sound design and rugged construction assure years of trouble-free, profitable operation. Check the features shown opposite and below, and for full details send right away for your free copy of catalog, No. K82-G.



REEVES Variable Speed Transmission embodies the proved operating principle of a V-belt driving between two pairs of cone-shaped discs, mounted on parallel shafts and adjustable to form an infinite number of driving and driven diameters. One shaft receives power at constant speed from motor, line shaft, etc. Other shaft delivers power at infinitely variable speeds to driven machine. Each speed setting is held without fluctuation.

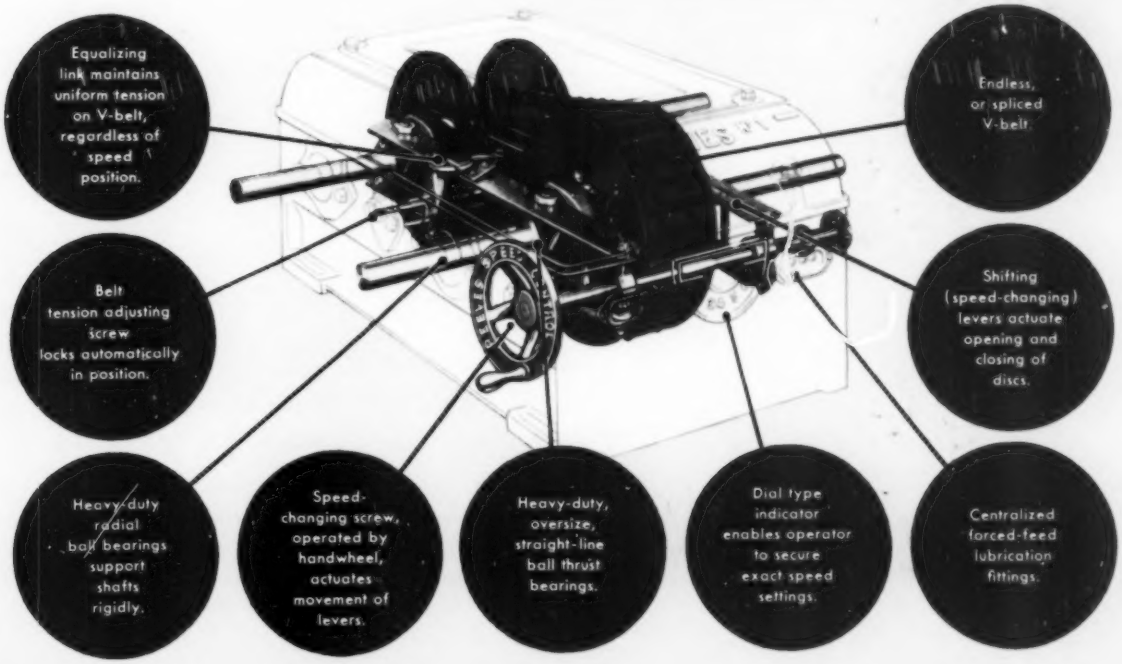
REEVES PULLEY COMPANY • COLUMBUS, INDIANA

Recognized leader in the specialized field of variable speed control

Accurate · Variable

REEVES

SPEED CONTROL


Equalizing link maintains uniform tension on V-belt, regardless of speed position.
Belt tension adjusting screw locks automatically in position.
Heavy-duty radial ball bearings support shafts rigidly.
Speed-changing screw, operated by handwheel, actuates movement of levers.
Heavy-duty, oversize, straight-line ball thrust bearings.
Dial type indicator enables operator to secure exact speed settings.
Centralized forced-feed lubrication fittings.
Shifting (speed-changing) levers actuate opening and closing of discs.
Endless, or spliced V-belt.

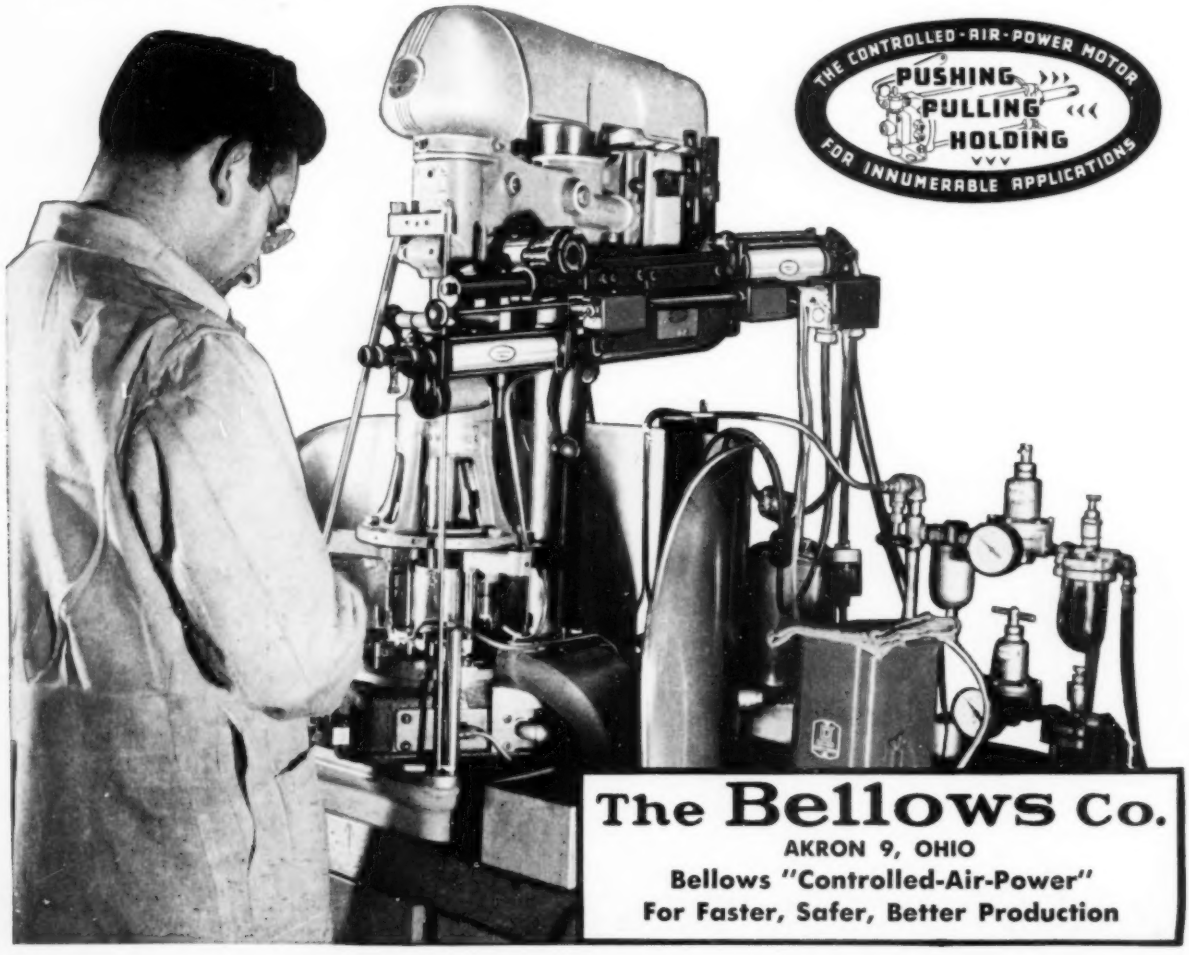
BULOVA WATCH CO. FINDS HIGH ACCURACY—LOW COST—IN MACHINING WITH AIR POWER

HIGHEST standards of accuracy are characteristic of Bulova Watch Company—in product, and in manufacturing processes. Hand in hand with high accuracy goes close cost control, and continual searching for new ways of doing old jobs better.

Typical of Bulova's approach to manufacturing problems is their use of Bellows "Controlled-Air-Power" Devices to automatize tedious, costly hand operations. For example, in this set-up for blind hole drilling and counter sinking (a common hand operation), Bulova uses a Bellows Drill Press Feed to feed a multi-spindle drill press, and a Bellows Rotary Work Feeder to position parts under the spindle. Both Bellows units are electrically inter-locked and controlled. The work of the operator is reduced to loading and unloading. Production is a steady 500 per hour and parts are finished to hair line accuracy.

Today, in thousands of manufacturing plants in all lines of industry, alert production men view every repetitive manual operation with a critical eye, asking, "Can we do it better with Bellows 'Controlled-Air-Power' on the job?"

We would like you to see our latest Foto Facts File showing applications of "Controlled-Air-Power" in many of these plants. It's yours, on request, without cost or obligation. Write The Bellows Co., Akron 9, Ohio, and ask for a copy of the current Foto Facts File. 601-A



The Bellows Co.
AKRON 9, OHIO
Bellows "Controlled-Air-Power"
For Faster, Safer, Better Production

DOUBLE PROTECTION FOR BEARINGS

1. Keeps oil and grease in

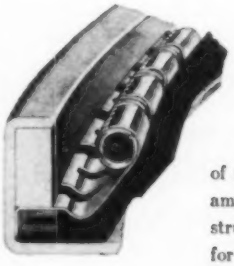
2. Keeps dust, dirt and water out

Bearings *last longer* and require *less maintenance* when they're protected by Garlock KLOZURE Oil Seals. These superior oil and grease seals keep the lubricant sealed *in*—keep dirt and contaminating materials locked *out*.

Garlock KLOZURES are produced in a wide range of sizes including Metric to fit standard International Millimeter ball and roller bearing housings. *For complete information write for Klozure Catalog No. 10.*

THE GARLOCK PACKING COMPANY
PALMYRA, NEW YORK
In Canada: The Garlock Packing Company of Canada Ltd., Toronto, Ont.

Specially Designed KLOZURE Oil Seals

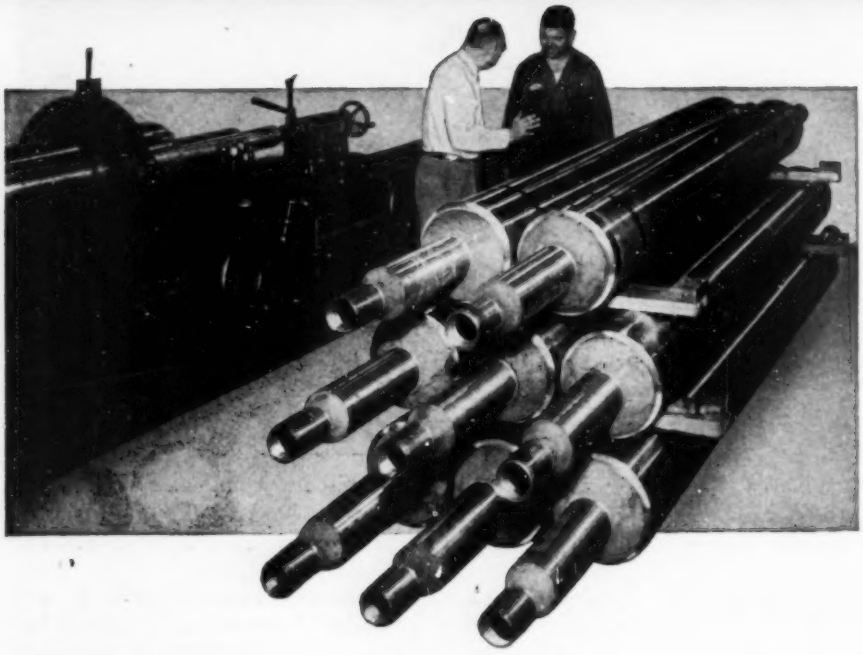


For those applications for which none of our regular KLOZURE models are suitable we design and manufacture oil seals of many special types. Examples of such special constructions are . . . small seals for needle bearings . . . seals for self-aligning or spherical bearings . . . and heavy duty seals as illustrated at the left for steel mill roll necks or other shafts of large diameter. If you have a bearing seal problem let our experienced technical staff solve it for you.

GARLOCK Klozure* Oil Seals
For all types of bearings

*Registered Trademark

MISCO *Stainless Steel*
Conveyor Rolls
For Heat and Corrosion Resisting Service
LIGHT · SOUND · STRONG · ACCURATE



Misco 18-8 Lehr rolls, 19'-0" overall length. Roll body 13" diameter x 12'-11" long. Finished weight 1700 pounds.

MISCO STAINLESS STEEL ROLLS are made by welding pairs of end trunnions to centrifugally cast tubes.

They are available from 3½" to 24" O.D. with smooth cast finish, or with bodies machined or ground to a high degree of accuracy. We can supply finished rolls up to 20'-0" long.

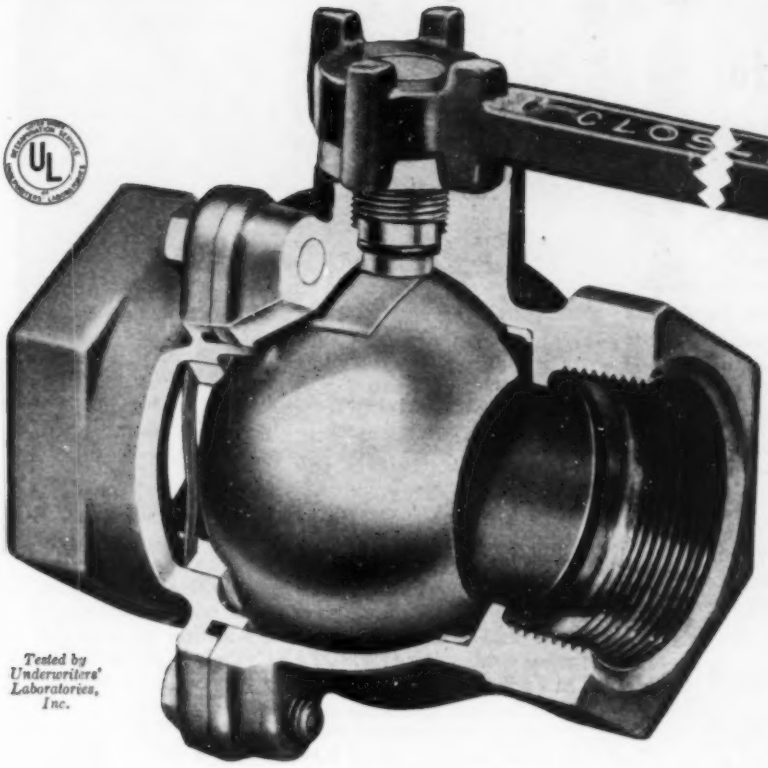
Hundreds of Misco Centricast Rolls of various types are giving dependable service at temperatures up to 2050°F. When you need stainless steel rolls send your inquiries to Misco. We have excellent facilities to serve you.

ALLOY CASTING DIVISION
Michigan Steel Casting Company

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys

1996 GUOIN STREET · DETROIT 7, MICHIGAN

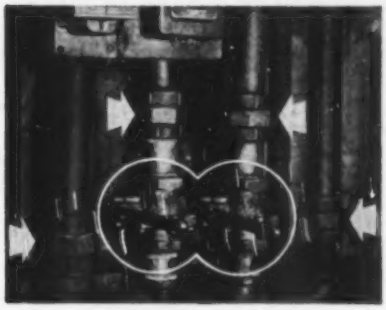
MISCO
Heat and Corrosion Resistant Alloys



Tested by Underwriters' Laboratories, Inc.

Underground, tests 4" cast iron water pipe. Operates 600 times a day. Says Warren Pipe Company's plant engineer . . . "Rockwood Cast Steel Valve is definitely superior to any other . . ."

On High Seas, in discharge manifolds, Rockwood Ball Valves perform perfectly under hazards of salt water, fish scales, wood splinters and dirt. "Outwear and outperform all valves previously used," says Hub Machine Company.



At Annealing Furnace of Revere Copper and Brass, Inc., Rockwood Ball Valves are used for quenching 60 times a day under 100 p.s.i. "They last four times longer than others," says user.

EARTH, WATER OR FIERY-FURNACE . . .

Rockwood Ball Valves outperform around all three!

Sure they're tough! Rockwood Ball Valves are made that way. In industry after industry under the most gruelling of conditions they do what they're supposed to do:

(1) Give leak-proof service . . . (2) maintain a full round flow . . . (3) open and close quick and sure. They are so engineered that they stand up to the job without maintenance and for long life. They push up profits because they cut costs.

The industries which benefit by their superior performance include chemical, food, paper, textile, petroleum and others. Come in all pipe sizes from ½" to 4" for 300 p.s.i. working pressure. Send coupon.

ROCKWOOD *FULL-FLOW* BALL VALVES

THE FLOW IS AS ROUND AS THE PIPE ITSELF

ROCKWOOD

ROCKWOOD SPRINKLER COMPANY
106 Harlow St., Worcester 5, Mass.

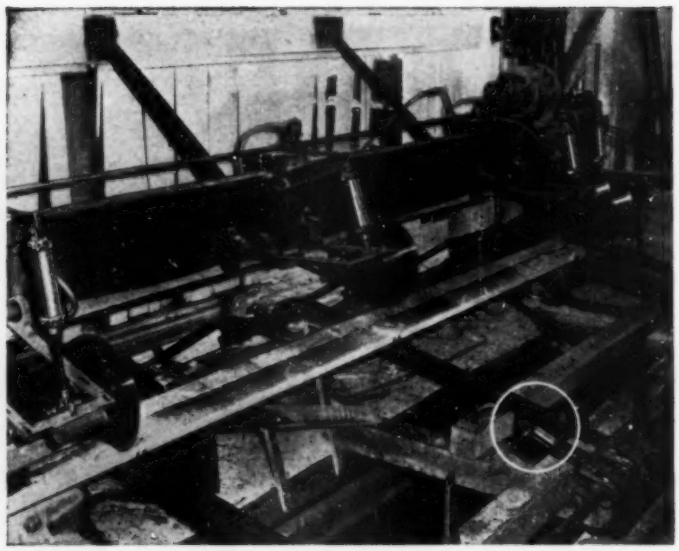
Please send me without obligation your comprehensive booklet describing Rockwood Ball Valves.

Name .....
Title .....
Company .....
Street .....
City .....
Zone ..... State .....

Air Feed for TRIM SAWS..with NOPAK Air Cylinders

This 8-saw trimmer installation at Lumber Mills Corp., Ashland, Ore., utilizes NOPAK Model "E" cushioned Air Cylinders to "feed" the saws to the work. As the Link-Belt conveyor chains carry the lumber toward the trim saws, only the two saws which cut the boards to commercial lengths with minimum waste are lowered by the NOPAK Cylinders. The cylinders may be actuated by manually operated or automatic valves.

NOPAK Cylinder, located under conveyor chain, powers flipper arms which transfer boards from preceding conveyor chains at lower right.



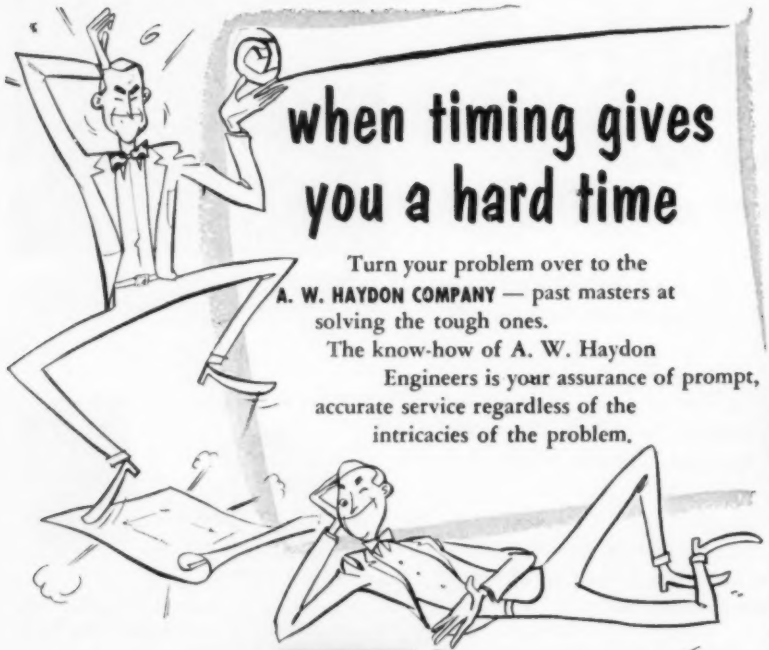
Photograph, courtesy of Link-Belt Co., shows NOPAK Model "E" Cylinders used in conjunction with Link-Belt conveyor chains and pillow blocks.

This is one of many lumber mill installations employing NOPAK Cylinders to move saws into cutting position. (Others are shown in the NOPAK Application Manual.) It may suggest similar uses for NOPAK Cylinders and NOPAK Valves in your plant, or in machinery you build for resale.

For Data and Dimensions refer to Sweet's File for Product Designers, or write for Bulletin SW-1.

NOPAK
VALVES AND CYLINDERS
DESIGNED for AIR and HYDRAULIC SERVICE

GALLAND-HENNING MFG. CO.
2762 SOUTH 31ST STREET • MILWAUKEE 46, WISCONSIN
Representatives in Principal Cities



when timing gives you a hard time

Turn your problem over to the **A. W. HAYDON COMPANY** — past masters at solving the tough ones.

The know-how of A. W. Haydon Engineers is your assurance of prompt, accurate service regardless of the intricacies of the problem.

Send for catalog.

Would you like to work with us? We need qualified engineers *now*. Excellent opportunities for men who are looking to the future.

The **A.W.HAYDON COMPANY**
221 NORTH ELM STREET
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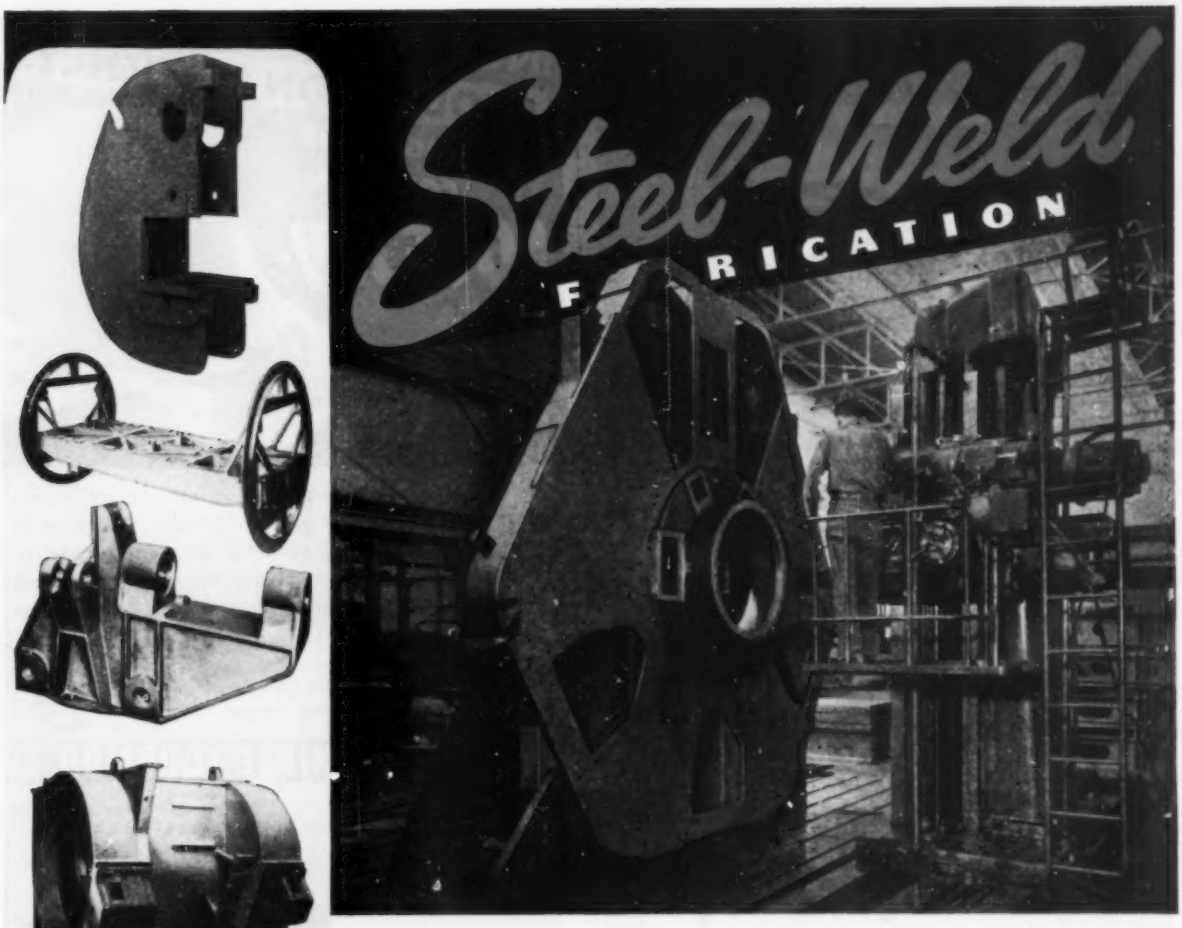
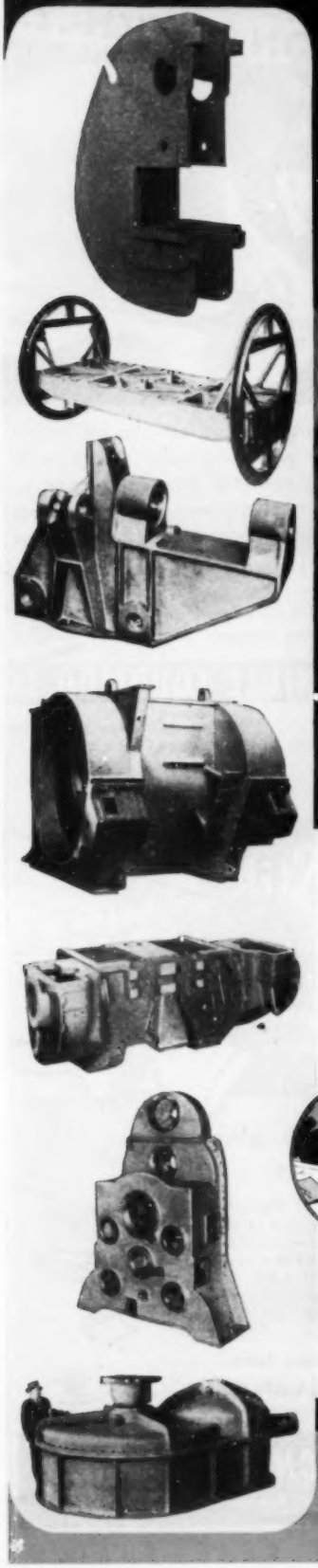
Design and Manufacture of Electrical Timing Devices

Made of tough, durable Ethyl Cellulose plastic. This cable clip will hold wires or groups of wires neatly and securely in position . . . no possibility of shorts or grounds. Only one fastener is required (screw, nail, rivet or eyelet) with these loop type supports.

Write for samples details, prices

WECKESSER CO.
ALSO MFRS. OF ALL NYLON CABLE CLIPS
5265 N. Avondale Ave. • Chicago 30, Ill.





Use WELDED STEEL for Greater Strength with Less Weight!

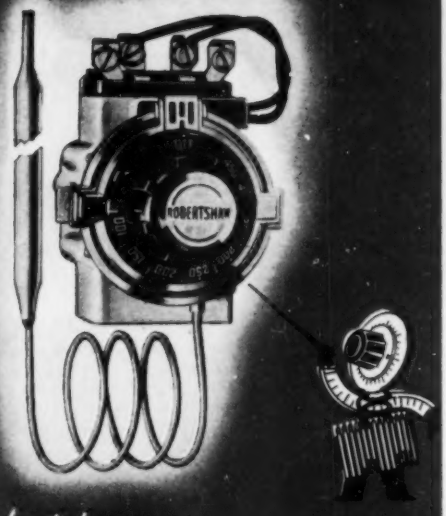
Above is another excellent example of Mahon versatility in the production of Steel-Weld Fabricated units for many industries. This base, undergoing machining operations, was produced for a TV picture tube manufacturer in the glass industry...it is typical of thousands of Steel-Weld Fabricated parts and assemblies produced and machined by the Mahon Company for manufacturers throughout the country. If parts or assemblies in your product could be redesigned and produced to better advantage through Steel-Weld Fabrication, or, if you are faced with a limited production of a product involving heavy pieces in which pattern costs are a consideration, you can turn to Mahon with complete confidence. You will find in the Mahon organization a unique source with complete, modern fabricating, machining and handling equipment to cope with any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job, embodying every advantage of Steel-Weld Fabrication.

THE R. C. MAHON COMPANY
DETROIT 34, MICHIGAN

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

DEPENDABLE



Robertshaw D-1

Heat Control FOR MANY USES

For melting pots for solder, wax, plastics, etc.
For hot water boosters and water heaters.
For urns, fryers, ovens, cooking equipment.
For automatic heat sealing machinery.
For sterilizers and similar applications.
For label dispensers, heating equipment, etc.

Here's a highly sensitive, accurate control ruggedly constructed and designed to meet a wide variety of heating applications with a maximum temperature range of 550° F. It is a double pole, single throw, direct acting control. No separate "off" switch is required. The mechanism is actuated by a hydraulic thermostatic element consisting of a bulb, capillary tube and diaphragm. (Also available in reverse acting types.)

Write for full information.

In Home and Industry *EVERYTHING'S UNDER CONTROL*

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THERMOSTAT DIVISION

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INCREASE PRODUCTION EFFICIENCY...

with FINGER-TIP CONTROL

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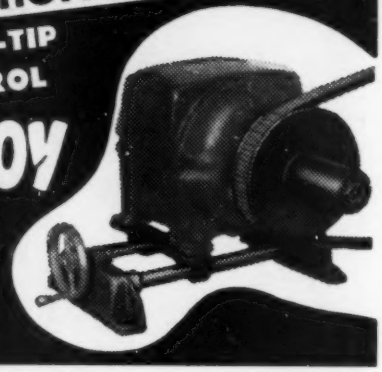

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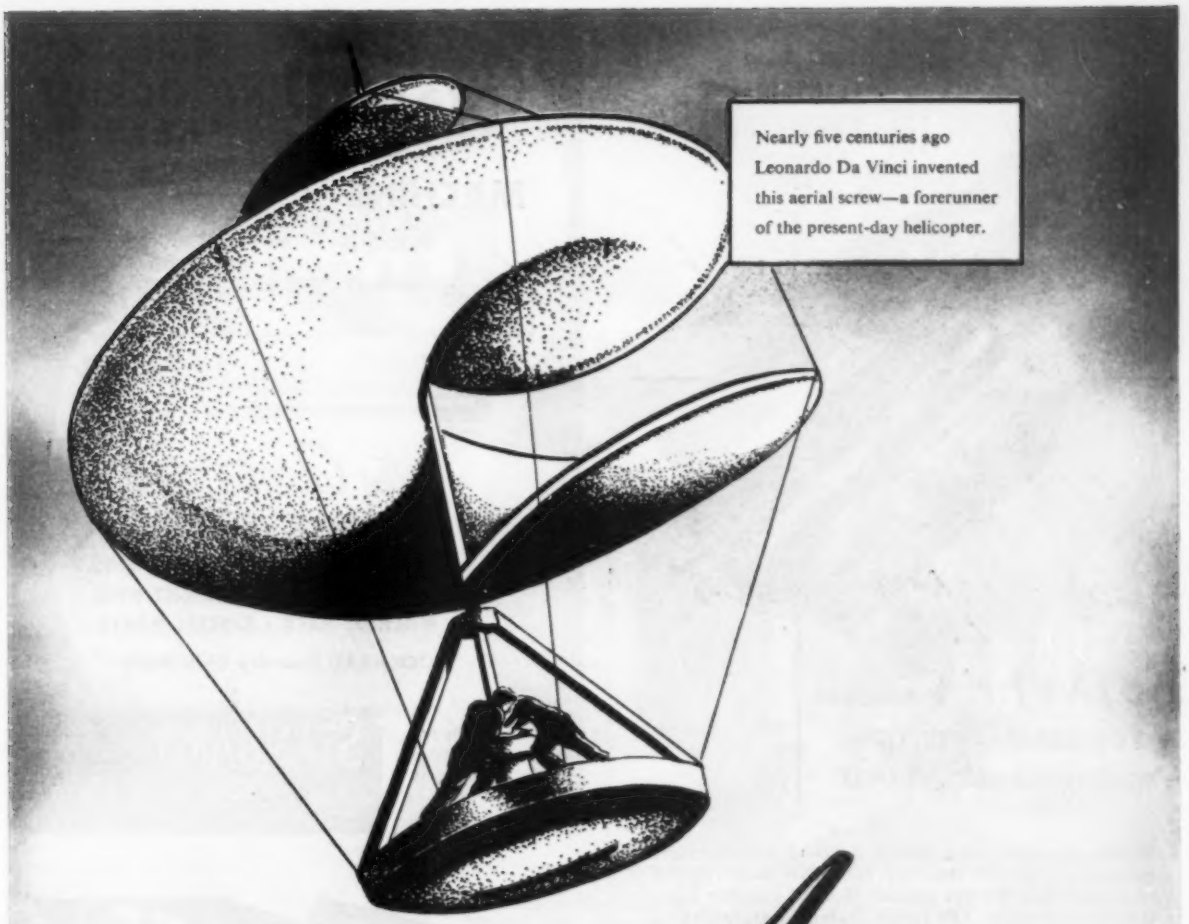

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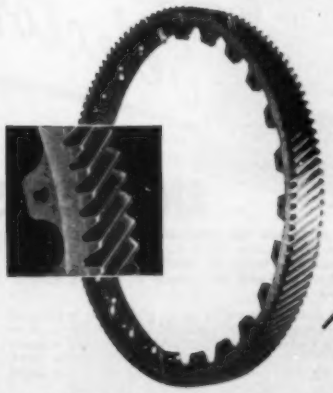

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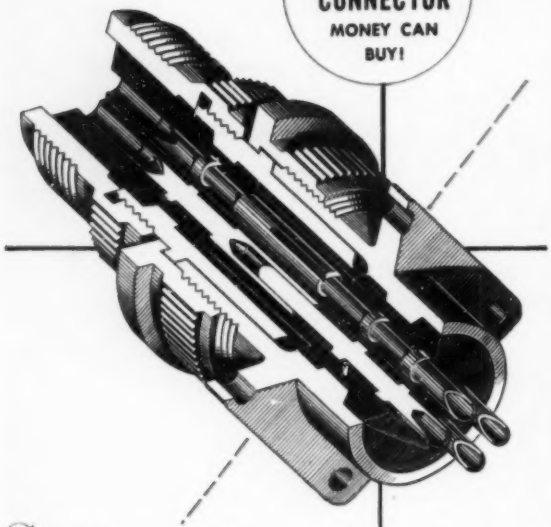

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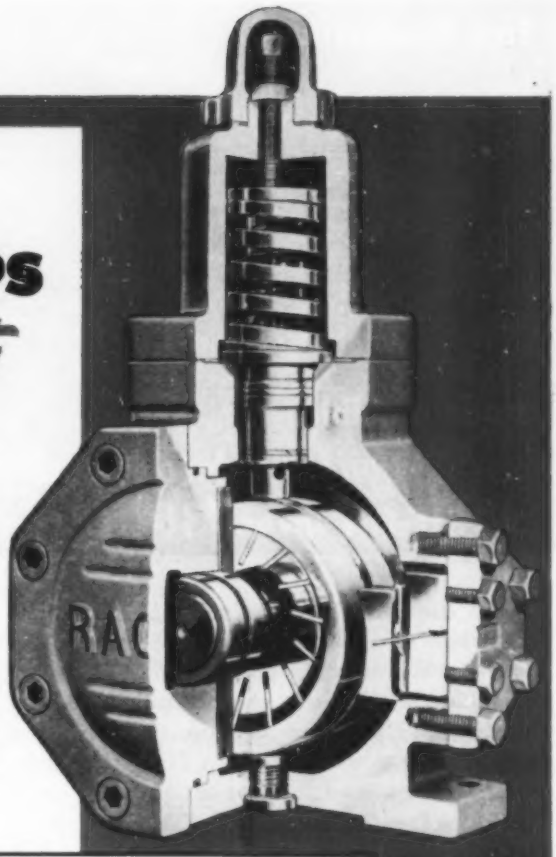
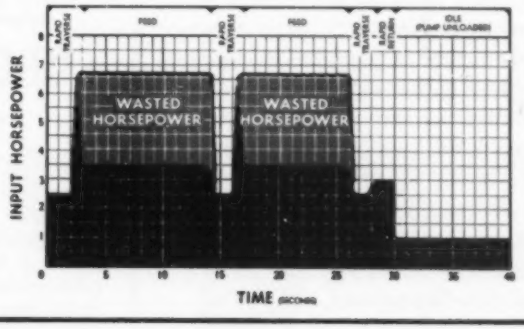


Chart below illustrates power consumption on a typical machine tool. Black area is power used with a No. 2 RACINE *"Variable Volume" pump controlled by a pressure compensated feed valve. Area in color is power wasted by a constant volume pump, bypassing most of its volume through a relief valve during the feeding cycle.*



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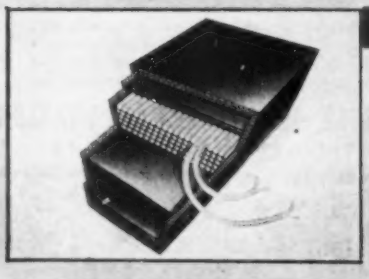

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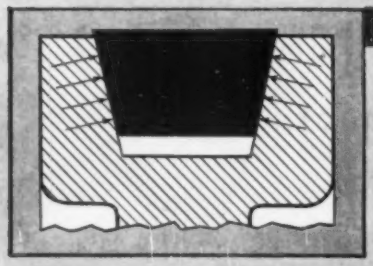

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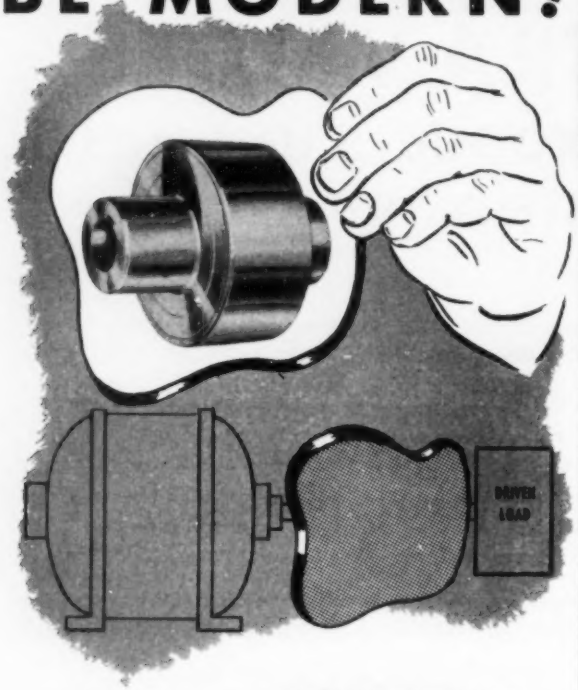

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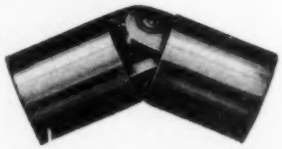

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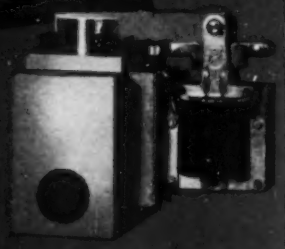

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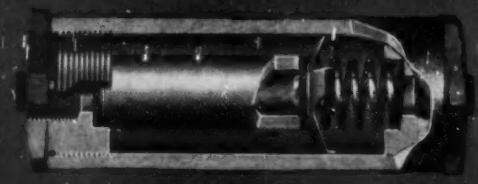

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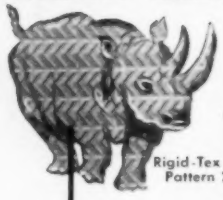

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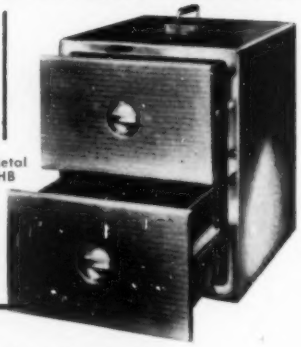

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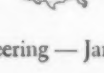

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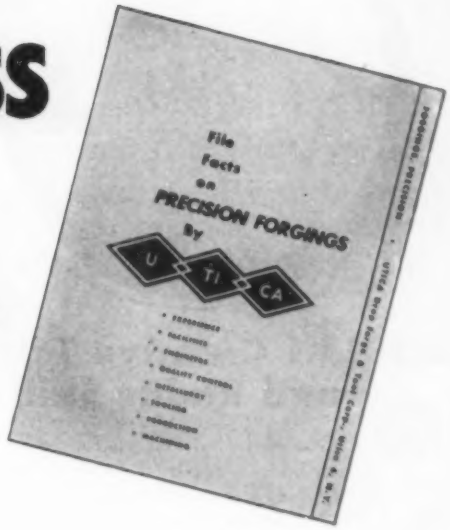

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2921 WEST OLIVE ST., BURBANK, CALIFORNIA

P-M SMALL METAL STAMPINGS

PATTON-MacGUYER

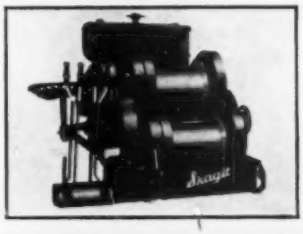
For over 33 years P-M has been a dependable source for small metal stampings. An extensive modern plant, complete equipment, specialized engineering experience and toolmaking skill combine at P-M to produce stamped metal parts accurately, economically, promptly. Moderate die charges. Modern facilities for large volume production. Special stamping problems are gladly accepted; recommendations for the most efficient and economical solutions are made promptly. Send prints for your next stamping job to P-M.

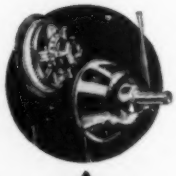
TERMINALS for ELECTRIC WIRES

Being long experienced specialists in the terminal field, we have dies to produce over 400 different kinds of separate terminals, and every modern facility to meet your standard or special requirements. We also provide terminals in continuous form, supplied on reels, with machine for attaching and soldering tandem terminals to wires in one continuous operation. Send for folder.

PATTON-MacGUYER COMPANY
Baker Street & Virginia Avenue, Providence 5, R. I.

Lift — Pull — Haul





Hold — Lower — Load

The Skagit Steel & Iron Works, SERIES "G" HOIST handles lumber or industrial loads easily, safely and with precision. ROCKFORD CLUTCHES contribute to the reliability and efficiency of this handy unit. Let ROCKFORD clutch engineers help your product designers lay out power transmission controls that will give your machines competitive advantages.

ROCKFORD CLUTCH DIVISION BORG-WARNER
209 Catherine Street, Rockford, Illinois, U. S. A.

B-W ENGINEERING MAKES IT WORK
B-W PRODUCTION MAKES IT AVAILABLE
ENGINEERING BULLETIN SENT ON REQUEST

ROCKFORD CLUTCHES

TORQUE CAPACITIES FROM this

you'll get dependable, smooth power delivery when you specify

BLOOD BROTHERS

Universal Joints

FOR AGRICULTURAL, AUTOMOTIVE, INDUSTRIAL, MARINE AND CONSTRUCTION EQUIPMENT APPLICATIONS

K Series K2R Series	Maximum Torque Inch Pounds Continuous Load	Hand Operation
K-1-C	350	2,000
K-2-A	350	5,000
L6S Series L6N Series	400	2,000

	Recommended Torque Rating, Inch Pounds Needle Bearings
L10S Series	650 Optional
1FR Series	1,080 "
L14S Series	1,230 "
3DR Series	1,800 "
L16S Series	2,200 "
35N Series	10,000 "

N Series	Recommended Torque Rating, Inch Pounds Balanced for
45N	14,000 3600 R.P.M. Max.
5N	20,000 "
50N	20,000 "
6N	38,000 "
60N	38,000 "
7N	57,000 "
70N	57,000 "
75N	70,000 "

BW Series	Maximum Torque Inch Pounds Continuous Load	Momentary Load
BW-12	1,020	4,450
BW-1	1,695	7,500
BW-2	3,350	11,720
BW-3	4,450	16,800
BW-4	5,080	22,900
BW-5	8,640	34,200
BW-6	11,620	60,000
BW-7	28,600	150,000
BW-9	89,300	500,000

*Extra shock-load capacity built into all sizes.

Need a moderately small universal joint on your next project — for a hand-operated control rod, for example? Blood Brothers has it! In fact, you can select from any of four Series — all widely used on farm implements, road and construction machinery, tractor steering assemblies, etc.

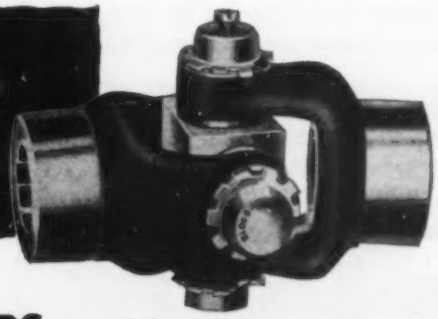
Or do you need a source for high speed joints and propeller shaft assemblies for trucks, busses or other mobile equipment? Blood Brothers builds a wide selection of automotive assemblies with torque capacities to 70,000 inch pounds.

For really heavy work, look at the BW Series — for transmitting up to 1,400 H.P. with momentary loads reaching 500,000 torque inch pounds! It's the largest commercial universal joint made — and Blood Brothers makes it.

Thus, when you specify Blood Brothers, you can select from a wide range of torque capacities . . . and be confident of top-quality universals that contribute dependability and smoothness to your product's performance.

For details, contact Blood Brothers, stating your specific problem. We'll be glad to cooperate with engineering suggestions.

TO this



BLOOD BROTHERS machine co. ALLEGAN, MICHIGAN

UNIVERSAL JOINTS AND DRIVE LINE ASSEMBLIES

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Are you SURE you're using THE MOST EFFICIENT FINISH?

If your production involves finishing zinc, cadmium, aluminum or cuprous metals, you owe it to yourself... and your customers... to investigate

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IF YOU WANT HIGH CORROSION RESISTANCE,
you'll find an Iridite that will meet any military or civilian specifications for chromate finishing.

IF PAINT ADHERENCE IS IMPORTANT,
you'll find Iridite prevents underfilm corrosion and soap formation.

OR, FOR BRIGHT, DECORATIVE FINISHES—

investigate zinc plate and Iridite (Bright) for a chrome-like decorative finish with more corrosion protection than conventional chrome plating . . . or Iridite (Metcote) as a treatment for copper that eliminates the need for buffing in the copper-chrome system; produces a sparkling bright finish!

Write for literature and send us samples for test processing. See "Plating Supplies" in your classified telephone directory or write direct.

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for Corrosion Protection and Paint Systems on Non-Ferrous Metals; ARP Plating Brighteners.
West Coast Licensees L. H. BUTCHER COMPANY

*empirical data or implicit functions

Precision Potentiometers by Technology Instrument Corporation are designed for application in computing devices instrumentation, electronic control and servo mechanisms — wherever extreme electrical and mechanical precision is an essential requirement.

As a result of years of custom manufacturing a complete line of standard sizes is available, ranging from 7 inches in diameter to the subminiature ⅞" in diameter.

Type RVP3 tapped hole and precision pilot mounting

RV1 Servo mounting

Custom design both mechanical and electrical is a featured TIC service. Precision non-linear pots may be designed to meet customer's requirements from either **empirical data or implicit functions.* Taps and special winding angles anywhere up to 360° continuous winding can be incorporated into both linear and non-linear precision potentiometers. Greatly expanded facilities plus mass production techniques meet customer volume needs yet maintain precision tolerances in both linear and non-linear potentiometers.

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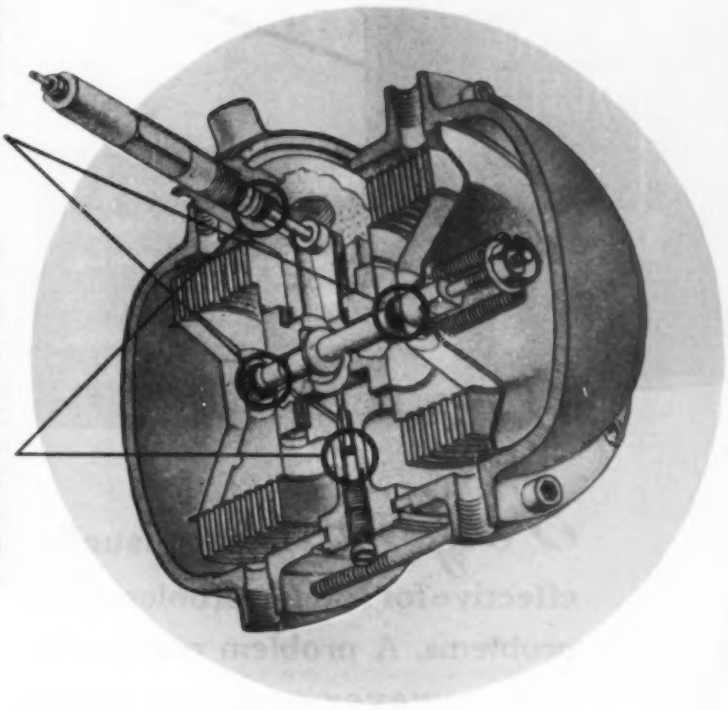
TIC TECHNOLOGY INSTRUMENT CORP.

539 Main Street, Acton, Mass.
Telephone: Acton 3-7711

Tight Shut-off here protects the Barton Flow Meter against pressure overloads up to 4500 psi. LINEAR "O" rings on the valve stem make an extremely simple, compact valve that seats tightly . . . gets even tighter as pressure increases—impossible with conventional packings.

Vapor-tight seals here prevent leaks that would destroy the instrument. Several of the points sealed with LINEAR "O" rings are subject to both rotary and reciprocating motion. Others are simply static seals. LINEAR "O" rings permitted considerably more compact and less expensive construction than conventional packings . . . and provided complete safety that could not otherwise have been obtained.



Simple, economical design made possible with Linear "O" Rings

Seal it tight . . . make it small . . . keep design simple and economical. These were the requirements that faced the designer of the Barton Flow Meter. Service conditions were tough, too; pressures up to 4500 psi, temperatures from -20 to 200° F. But on every count, LINEAR "O" rings proved the best answer to sealing problems.

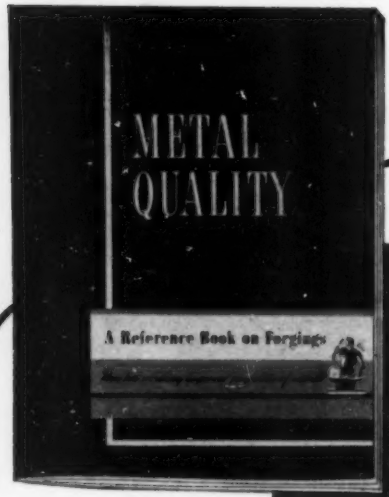
As Barton's vice-president, Claude B. Nolte reports, "The LINEAR "O" rings permit a compact and simple construction which would have been difficult to achieve with conventional packings. Without them, the instrument would unquestionably have been more bulky and more expensive to produce."

Perhaps your product, too, can be simplified, reduced in size, or made at lower cost through the use of Linear "O" rings. Write or call LINEAR for full information.

"PERFECTLY ENGINEERED PACKINGS"

LINEAR

LINEAR, Inc., STATE ROAD & LEVICK ST., PHILA. 35, PA.



Engineering, production and economic advantages obtainable with forgings are presented in this Reference Book on forgings. Write for a copy.

Forgings are unusually effective for solving problem part problems. A problem part problem, however complex, often ceases to be a problem once all the aspects of the part are checked with the unrivaled economic and mechanical advantages of closed die forgings and the closed die forging process for producing parts. Whatever the nature of problems that make a problem part, consult a forging engineer to determine the extent to which forgings can help you solve them.

DROP FORGING ASSOCIATION
605 HANNA BLDG. • CLEVELAND 15, OHIO

Please send 60-page booklet entitled "Metal Quality—How Hot Working Improves Properties of Metal", 1949 Edition.
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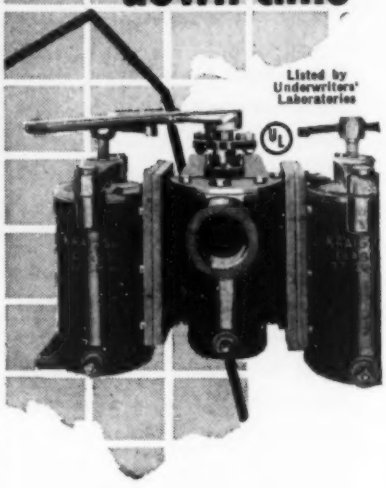
"SINCE 1936" in the application, design and mfg. of pumps — separators — hydraulic accessories.

cut "down time"



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SINGLE AND DUPLEX SEPARATORS — for both Standard and High Pressure operations — designed and engineered to give maximum protection to every supply line carrying diesel oil or lubrication oil —also steam lines; lubricating lines, cooling water service, and grease separators.

You can have any practical degree of separation — from primary straining to secondary filtration.

Baskets instantly and easily changeable — without tools. Magnet equipped type for lubricating lines, etc. — where metallic particles give trouble. Economical, too . . . Kraissl Separators entirely eliminate your normal filter replacement costs. The simple cleaning of Kraissl filter baskets restores original efficiency.

Write today for Bulletin A-1214

KRAISSL THE KRAISSL COMPANY, Inc.
HACKENSACK, N. J.

Get the facts straight about

TIN

Tin is vital to the free world . . . indispensable to this nation's health, industrial progress, transportation, communications, standard of living, and security.

Tinplate, for example, is strong, can be soldered easily, can be lacquered and lithographed beautifully, and is absolutely nontoxic. In solder, tin wets metals readily, flows easily, and seals sound joints. Tin resists corrosion, too, and is highly malleable.

Yet we continue to seek substitutes for tin . . . continue to strive for that elusive something "just as good."

WHY?

Does it make sense to try to replace one of the most economical production metals known to industry?

Does it make sense when Malaya, the world's largest tin producer and one of the free world's staunchest allies, stands ready to supply tin on a free market for whatever the demands of American industry may be?

It is the purpose of this Bureau to furnish accurate information about tin to American industry, and to promote a clearer understanding between the United States and Malaya.

One of the media used to accomplish this is a monthly newsletter. We'd like to send "Tin News" to you regularly, and with our compliments. All you need do is tell us you'd like to get it.

THE MALAYAN TIN BUREAU

Department 461

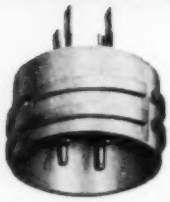
1028 Connecticut Avenue, Washington 6, D.C.

MALAYAN

BUREAU

THERE IS NO REAL SUBSTITUTE FOR TIN

CANNON PLUGS *for hermetic sealed applications*



KH

RKH

HERMETIC SEALED Type RKH Plugs and KH Receptacles mate with their corresponding Cannon RK and K standard fittings. The basic construction of fused vitreous insulation around the contacts is same as GS type. Shell materials and finish are likewise similar. Various types of flange or hex-bulkhead styles may be made to order.

Refer to KH-1 Section in K Bulletin.

SUB-MINIATURE receptacles of the new Cannon "U" Series are used on miniature switches, relays, transformers, amplifiers, and other sealed components, requiring a true hermetic seal or a connector of sub-miniature size with performance superiority.

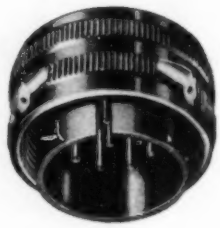
"U" plugs have a steel shell and "SILCAN*" insulator, cable relief and moisture resistant sleeve.

Bayonet-type locking means prevents vibration failure. Rated 1700v. d.c.; 5a. Available in 3, 6, and 12 contact arrangements with one plug style and two receptacles.

**Cannon Electric's special silicone resilient material.*

Refer to U-2 Bulletin

GS02



GS06

GS Types mate with standard AN(MIL) types. These highly successful hermetically sealed plugs (GS06) and receptacles (GS02) pioneered this field and are top quality fittings. Fused vitreous insulation provides a true hermetic seal for relays, position indicators, etc. Shells are steel, finished in cadmium plate and bleached Iridite; coupling nut on plug is natural finish Dural. Eyelet or solder pot terminals.

Built to resist thermal shock, −300°F. to +600°F., surpassing MIL Spec. GS02 Types will withstand operation temperatures 400°F. to 600°F., and pressures as high as 200 to 900 psi; specials to 7500 psi. GS Types approximate AN voltage and current ratings. Wide range of AN layouts available.

See GS-3 section in AN-8 Bulletin for details.

COMING: TYPE "DH" HERMETIC SEALED CONNECTORS SIMILAR TO PRESENT DA-15P

CANNON ELECTRIC

Since 1915

Factories in Los Angeles, Toronto, New Haven, Benton Harbor. Representatives in principal cities. Address inquiries to Cannon Electric Co., Dept. A-106, P.O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.

There are good ideas for you in this report on how to tackle the problem of . . .

MATERIALS SUBSTITUTION

This Special Editorial Report contains the latest available data on the serious problem of materials substitution. You will find this 24-page report an invaluable information source about:

The short and long-range outlook in metal and non-metallic materials

Examples of what some big companies are doing in materials substitution

Factors to consider when substituting one material for another

How plastics can be used as substitutes for strategic materials

Specific data on substitutes for steel and other critical metals

New developments in metals and how industry plans to use them

Copies available at 35 cents each.

READER SERVICE DEPARTMENT

Product Engineering

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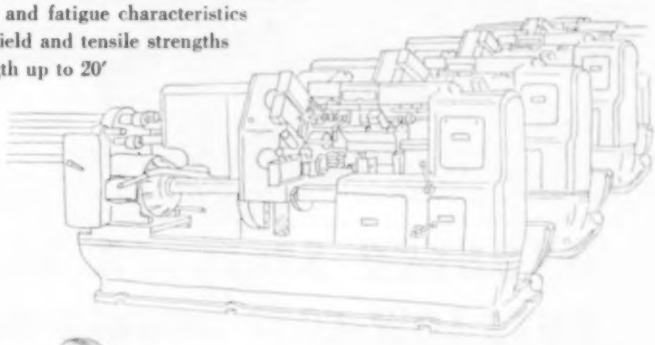
Customer Reports:

Asarco Continuous-Cast Bronzes Machined at Over 1,000 Feet Per Minute

WORTHINGTON CORPORATION has jumped machining speeds on shaft bushings and pump sleeves by using ASARCO Continuous-Cast Bronzes instead of foundry-cast bronzes. In some cases over 1,000 surface feet are machined per minute.

Worthington has used very substantial quantities of ASARCO Continuous-Cast Bronzes during the last three years in a variety of alloys and sizes. Tool life is longer despite high cutting speeds. Products are improved because ASARCO stock has greater uniformity than conventional foundry products, and its even dispersion of lead particles provides superior bearing surfaces.

ASARCO Continuous-Cast Bronzes are entirely free from porosity, and from hard and soft spots . . . are ideal for use on automatic screw machines. No sand, dirt, dross or other foreign matter is trapped in the stock to harm tools or discourage high cutting speeds. Dimensions are so precise that many machining operations are eliminated and waste is at a minimum. Impact and fatigue characteristics are up to 100% better than those of sand-cast bronzes. Yield and tensile strengths are superior, too. Stock is available in any length up to 20′ to meet individual requirements.



REDUCE MACHINING TIME! . . . IMPROVE PRODUCTS! . . . CUT SCRAP LOSSES! Buy ASARCO Continuous-Cast Bronzes and get bronzes with superior properties in the exact sizes you need.

ASARCO CONTINUOUS-CAST RODS · TUBES · SHAPES ®

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OFFICES: Perth Amboy Plant, Barber, New Jersey
Whiting, Indiana

HYDRECO SELECTOR VALVE PUTS LOW-COST DOUBLE DUTY IN "STRAIT-LINE" LOADER

Maine Steel, Inc. engineers designed this Strait-Line Loader to do a MAN-SIZE job . . . at modest cost. They specified a HYDRECO Selector Valve to operate the loader and dozer alternately — and saved the cost of a second circuit.

HYDRECO Selector Valves can work for you, too, operating the auxiliary hydraulic equipment on your product . . . and cutting costs in original equipment or on-the-job installations. HYDRECO Selector Valves are made in capacities of 5, 15, 25, and 50 gals./min. and for system pressures up to 1500 p.s.i.

Why not let a HYDRECO Application Engineer survey your oil-hydraulic control requirements. He is a specialist in Oil Hydraulic Pumps, Motors, Valves and Cylinder Assemblies. Write today for full engineering data.

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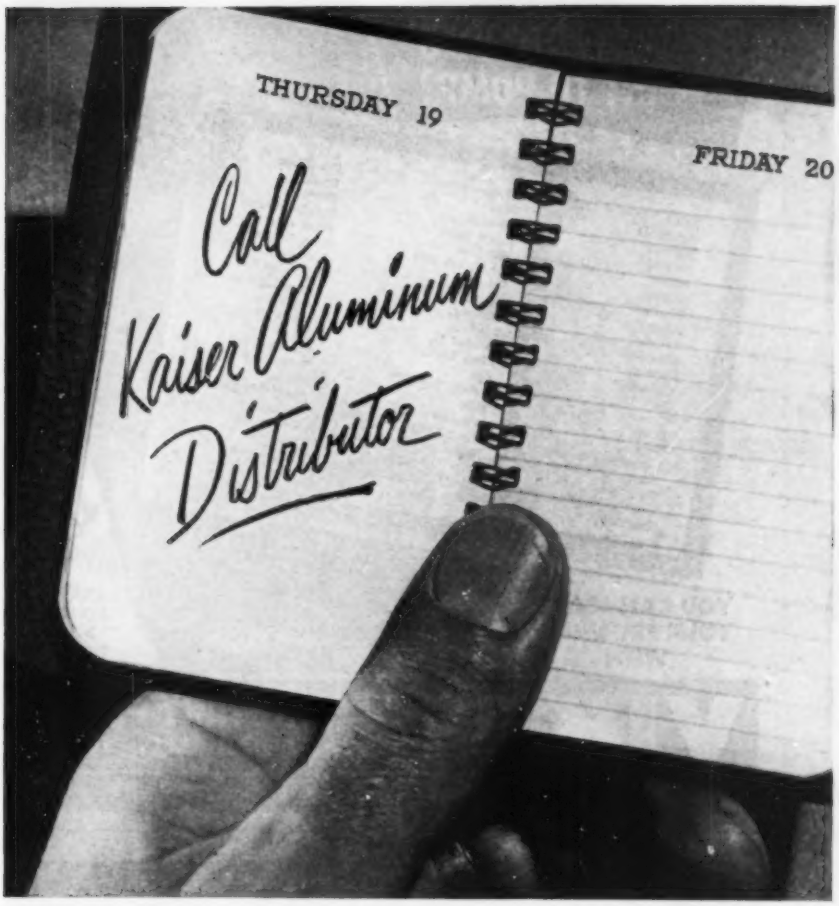


A good man to have around

WHEN you consider the *many services* your nearby Kaiser Aluminum Distributor offers you, it's clear why he's a good man to have around, whether the aluminum market is tight or soft.

He catalogs and stocks a large variety of aluminum forms—anticipates your needs so accurately that you get them with the least possible delay.

He gives you the advantage of his specialized knowledge on each of the items he stocks—helps you select the aluminum that's best for your particular job.

He studies new methods to help you stretch available aluminum supplies; furnishes experimental quantities; meets emergency needs.

He keeps abreast of ever-changing government requirements—often can supply the information necessary to help you obtain government orders and the aluminum to fill them.

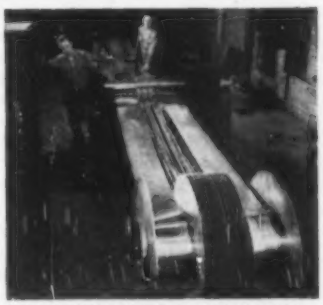
And because Kaiser Aluminum is building facilities which will increase its production of primary aluminum 137%, your Kaiser Aluminum Distributor may, sooner than you think, be able to increase your share.

It will pay you to visit your Kaiser Aluminum Distributor often.

HERE'S HOW YOUR DISTRIBUTOR HELPS YOU:

MORE VERSATILE INVENTORY—Large stocks maintained by your warehouse distributor give you the opportunity to select from a complete range of alloys and form.

LOWER COSTS—Specialization of warehouse plant and handling equipment permits deliveries at lower cost at machine side, cuts stock keeping and accounting costs.



LOWER RAW MATERIAL INVESTMENT—Slit, sheared, or sawed stocks to fit every production demand can be delivered to you daily. Eliminates expense of idle or obsolete inventory.

SMALLER SPACE REQUIREMENTS—Small lot purchases mean less space is needed to house raw materials. Result: you can devote more space to profitable production.

Your nearest Kaiser Aluminum Distributor is listed at the left. Call him TODAY!

Kaiser Aluminum

Setting the pace—through quality and service

Will Keep Your Assembly Lines at Peak Capacity

Whatever you manufacture or assemble, you can speed production and improve your product by using Pheoll screws, bolts and nuts. These industrial fasteners drive easy and straight, and will not bind because threads are accurately rolled or machined. Precision-made screw and bolt heads, slots and head recesses prevent wrench and driver slippage. Count, too, the added bonus you receive by using fasteners that improve product appearance.

An interesting story on standard and special industrial fasteners and their profitable applications to your needs may be obtained from experienced Pheoll engineers. Ask these men to recommend screws, bolts and nuts that will increase your overall profits on assembly line work.

these Pheoll products prevent production lag

Tapping Screws • Cap Screws • Sems • Phillips Recessed Head Screws and Bolts • Machine Screws • Special Fasteners • Thread Cutting Screws

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SCREWS BOLTS NUTS

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Acids	Glycerin	Petroleum
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Bleaches	Juices	Solvents
Blood	Kerosene	Soy Bean Oil
Cream	Lacquer	Sizing Liquids
Chocolate	Lard	Starch
Caustics	Linseed Oil	Syrups
Chemicals	Lime Water	Tar
Coal Tar	Lye	Tomato Juice
Creosote	Lubricating Oils	Turpentine
Drugs	Milk	Varnish
Dyes	Molasses	Vegetable Oils
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Ether	Naphtha	Water
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Food Products	Paints	Wine
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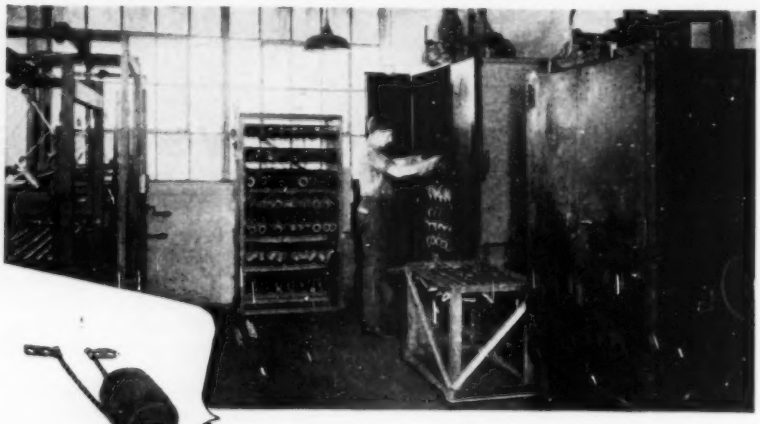
VIKING ROTARY PUMPS
CEDAR FALLS IOWA

THE ORIGINAL "*GEAR-WITHIN-A-GEAR*" ROTARY PUMP



Finished coil impregnated with varnish coating

Here at Coto-Coil . . .

. . . the Impregnating Department applies the final protective coating to precision-made Coto Coils. Each coil is pre-heated, immersed in varnish and drained . . . sometimes 3 or 4 times. The varnish finish, baked in these modern ovens, not only provides a hard, durable outer surface but completely fills all voids within the coil, resulting in a solid, pocket-free mass. Such modern production facilities, plus 35 years of experience, combine to make Coto Coils the first choice for engineered coils. Coto-Coil Company, 61 Pavilion Avenue, Providence 5, R. I.

Coto PRECISION WOUND **Coils**

Like the Thirteenth Doughnut in a Dozen

BAKER'S DOZEN, they used to call it, meaning something extra. We make the *something extra* in the world of steel . . . the high-alloy steels, special electrical alloys and magnetic materials that will do what ordinary metals never could do.

In equipment for peaceful uses or national defense: wherever the job needs something extra in strength, in resistance to heat, corrosion and wear, or in special electrical properties, that's where you'll find the products of the *Allegheny Ludlum Steel Corp. . . . General Offices: Oliver Bldg., Pittsburgh 22, Pa.*

PIONEER in Specialloy Steels

Allegheny Ludlum

W&D 3999

AL
TIME-TESTED STAINLESS STEEL

Purebon

SOLVES MANY PROBLEMS
caused by sliding or rotating parts which are DIFFICULT OR IMPOSSIBLE TO LUBRICATE

A constantly increasing stream of problems are facing engineers and designers today involving sliding or rotating parts where lubrication is difficult or impossible. For such applications, Purebon, the mechanical carbon, is often the ideal answer. Typical applications are seal rings, bearings, pistons, piston rings, pump vanes, valve seats, meter discs, and a host of similar items. Purebon comes in a wide variety of grades. It is strong, tough, readily machinable and in many cases can be molded directly to size.

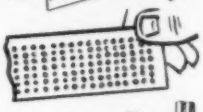
Bulletin No. 52 tells the complete story of Purebon. Write for your copy today.

PURE CARBON CO., INC.
448 HALL AVE. ST. MARYS, PA.

Originate your circuits this way and you're ready for PRACTICAL PRODUCTION

1. **MOUNT YOUR CIRCUITRY IN COMPACT VERTICAL PLANES USING ALDEN TERMINAL CARD MOUNTING SYSTEM.** Wiring, auxiliary components and miniature sockets assembled into completely mounted units readied for housing.

2. **ALDEN PRE-PUNCHED TERMINAL CARDS.** Terminal cards with prepunched holes on ¼" centers—available in varying lengths up to 3".



3. **ALDEN MINIATURE TERMINALS.** 4 sizes. Stake into Terminal Cards in any pattern. Hold components and leads firmly for soldering without wrap-around.

4. **ALDEN JUMPER STRIP.** Stake under terminals for common circuits, eliminating wiring. Snip off one you want to by-pass.

5. **ALDEN TERMINAL CARD MOUNTING SOCKETS.** Rivet or eyelet to card. Cards can be mounted to chassis via brackets or socket mounting plates.

HERE'S HOW ALDEN TERMINALS PERMIT PLUG-IN UNIT APPROX. 50% SMALLER: Mounting 3 condensers and 7 resistors on Alden Terminal Card, this 1 13/16" sq. plug-in unit has 20 Alden Miniature Terminals—plus 4-contact Jumper Strip—(in addition to tube sockets and plug-in base connections). For this same circuitry, solid turret type terminals would require the unit to be about twice this size—to allow space to manipulate, wrap around, solder.

Send for FREE ALDEN HANDBOOK and samples, or order Lab Kit No. 25, of comprehensive assortment of mounting cards, terminals, sockets. **Price $11.50.**

135 N. MAIN ST., BROCKTON 64, MASS.

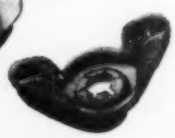
ALDEN PRODUCTS COMPANY

Vibration-proof Fastening—with BIG SAVINGS

PALNUT
TRADE MARK
LOCK NUTS
for quick, secure fastening at low cost

—cost less than plain nuts
—eliminate lockwashers
—speed up assembly
—save space, weight
—may be re-used

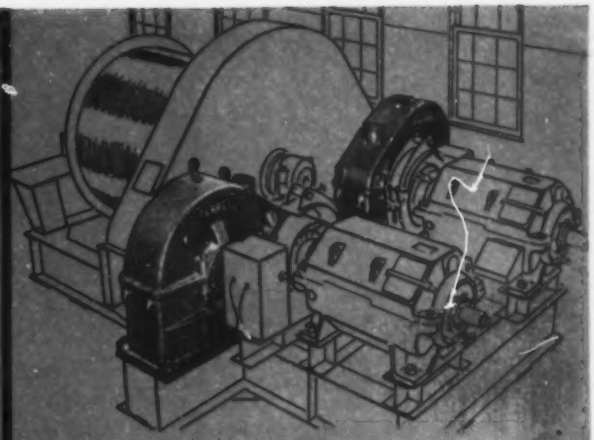
Check all your light duty nut-and-screw assemblies against the speed, savings and security of double-locking **PALNUT** Lock Nuts. Especially adapted to easy, fast power driver assembly of mass-produced items. Lock as they tighten, stay tight under severest vibration. Millions used monthly on all types of light assemblies.



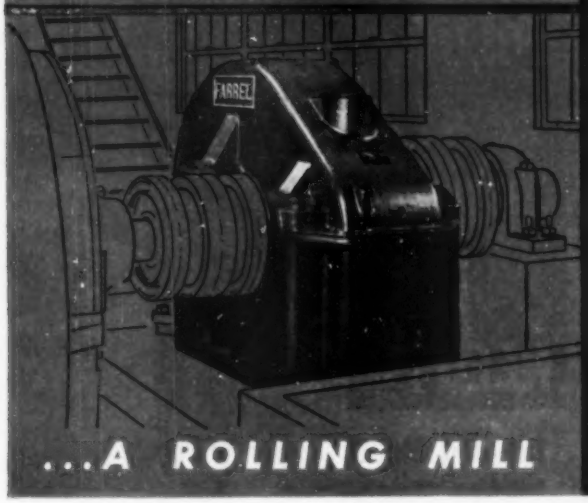
★ **For Free Samples, send details of assembly, screw size, etc. Ask for latest catalog showing complete line, uses, etc.**

THE PALNUT CO.
65 Cordier St., Irvington 11, N. J.
In Canada: P. L. Robertson Mfg. Co., Ltd., Milton, Ont.

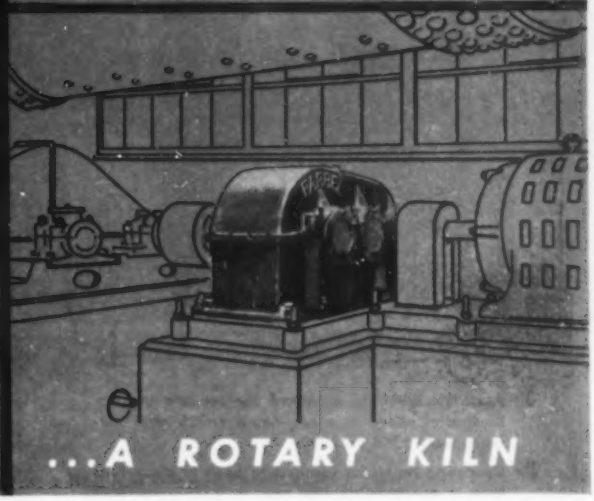
WHAT THE Design Flexibility OF FARREL® SPEED REDUCERS MEANS TO...



...A SKIP HOIST



...A ROLLING MILL



...A ROTARY KILN

FB-768

Design flexibility means the same thing in each of these applications: *a speed reducer that meets the drive requirements exactly.*

Farrel speed reducers, unlike most "standardized" products, are standard only in their principal features. They are adaptable in critical detail. Gears, shafts, bearings, and even some housing dimensions, can be proportioned to meet specific load, speed and service requirements. This flexibility has resulted in the solution of innumerable application problems.

In addition to this feature, Farrel speed reducers have a number of other advantages. The quiet, vibration-free performance of the herringbone gears results from extreme accuracy of tooth spacing, contour and helix angle . . . qualities inherent in the Farrel-Sykes method of gear generation. Precision manufacture and highest grade materials contribute to long gear life.

Shafts and bearings are factored to safeguard against interruption of vital processes. Gear cases are proportioned to withstand repeated heavy peak loads. Joints are sealed to prevent entrance of dirt.

Write for further details of these problem-solving units. Ask for a copy of Bulletin 449.

FARREL-BIRMINGHAM COMPANY, INC., ANSONIA, CONNECTICUT

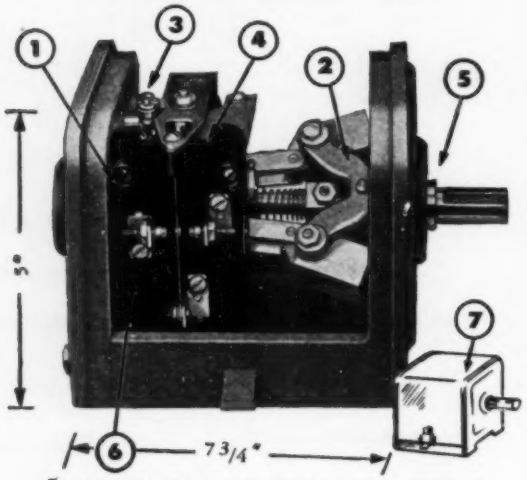
Plants: Ansonia and Derby, Conn., Buffalo, N. Y.

Sales Offices: Ansonia, Buffalo, New York, Boston, Pittsburgh, Akron, Detroit, Chicago, Memphis, Minneapolis, Portland (Oregon), Los Angeles, Salt Lake City, Tulsa, Houston, New Orleans

Farrel-Birmingham®

7 REASONS WHY EUCLID Centrifugal Switches are your answer

. . . for plugging, overspeed or underspeed protection, non-plugging and motion interlocking:



1. Available with any standard contact arrangement. Illustrated above is a two-circuit switch with normally open SPDT contacts.
2. Operating range for contacts to open or close runs from a minimum of 125 rpm to 2530 rpm. Safe maximum speed . . . 3600 rpm.
3. Ball-bearing engaging contact-making arm minimizes friction to assure trouble-free operation.
4. Contact-arm stops prevent undue wear of contacts.
5. Sealed and permanently lubricated precision ball bearings eliminate bearing maintenance.
6. Silver-to-silver contacts assure long life. When necessary, they are easily replaced. Snap-action contacts to assure quick make-and-break are available.
7. Available in dust-tight and oil-resistant enclosures for surface or flange mounting; and also in permissible enclosures for hazardous locations. Has Bureau of Mines approval.

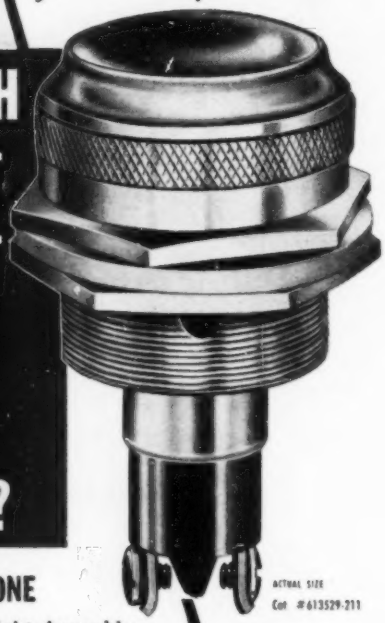
Thirty years of control application and manufacturing experience back this Euclid Electric & Manufacturing Centrifugal Switch which is finding wider and wider application on machine tools to increase production; on hazardous industrial machinery to increase safety; and for motion interlocking.

Ask your Euclid Electric & Manufacturing Co. Representative for complete information or write directly to us.

The Euclid Electric & Mfg. Co.
MADISON, OHIO

DIALCO
for **YOUR** *product*

WHICH PILOT LIGHT DO YOU NEED?



THE BIG ONE

This Pilot Light Assembly was first made to accommodate the *S-11 lamp* and was intended for use in the cabs of great diesel locomotives.

ACTUAL SIZE
Cat. #613529-211

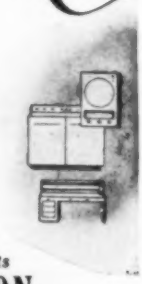
or

THE LITTLE ONE

The miniaturization program on defense products required the development of this *sub-miniature* light. It is used on communication equipment and aircraft. Midget flanged base bulbs to fit are rated 1.3, 6, 12, and 28 volts.

ACTUAL SIZE
Cat. #8-1930-621

Dialco HAS THE COMPLETE LINE of INDICATOR and PANEL LIGHTS



Samples to suit your own special conditions and requirements will be sent promptly and **without cost.** Just outline your needs. Let our engineering department assist in selecting the **right lamp** and the **best pilot light** for YOU.

Write for the Dialco HANDBOOK of PILOT LIGHTS

Foremost Manufacturer of Pilot Lights

DIALIGHT CORPORATION

60 STEWART AVENUE, BROOKLYN 37, N. Y. HYACINTH 7-7600

What makes the SNORKEL PEN "breathe"?

Sheaffer's new Snorkel Pen created a sensation when it was introduced to the trade. Using air alone, the pen is emptied, cleaned and refilled through the filling tube of the Snorkel Pen with a one-stroke touch-down action.

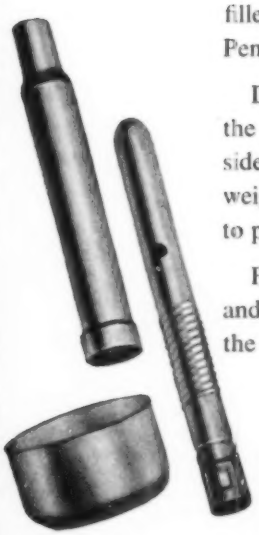
Designing the two brass "lungs" comprising the plunger-siphon mechanism called for considerable ingenuity. They must be light in weight, stiff and strong, easy to form and easy to polish and plate.

Formbrite* met all of these requirements—and more. With a metal thickness of only .0058", the 2" long cylinders are formed in multi-plunger presses in eight successive operations—*without annealing of any kind*.

Formbrite's superfine grain resulted in a harder, stronger, longer-lasting product with savings up to 50% in polishing costs.

Surprisingly, Formbrite, with all the plus values it offers over conventional drawing brasses, costs no more. See the reverse page for another application of Formbrite. And write for Publication B-39, addressing The American Brass Company, General Offices, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Limited, New Toronto, Ontario, Canada.

*Reg. U.S. Pat. Off. 5295



Cups like this, blanked and formed in one operation from Formbrite strip 1 1/16" x .0058", are magazine-fed into multi-plunger presses. Eight successive operations produce the sleeves illustrated at top of page *without annealing*. Sleeves at left are finished, ready for chromium plating.

Formbrite
is an
ANACONDA PRODUCT
Made by The American Brass Company

You can do this *better cheaper faster* IF THE METAL IS Formbrite

Since The American Brass Company introduced Formbrite* as a superior drawing brass, scores of stamping shops, polishing and plating rooms throughout the country have changed their thinking.

Comparative tests prove conclusively that the superfine grain structure of this specially processed forming brass means stamped and formed products that are stronger, harder, "springier" and more scratch-resistant. Yet the metal is so ductile that it can be readily formed, drawn and embossed.

Timestudies made of finishing operations have shown that a bright, lustrous finish can be obtained by a simple "color buffing" operation in half the time previously required.

That's why we say you can do it *better, cheaper and faster* with Formbrite. Millions of pounds of Formbrite sheet and strip have been produced and economically fabricated into hundreds of different products. Want a sample—and more information? Address The American Brass Company, General Offices, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Limited, New Toronto, Ontario, Canada.

5295

*Reg. U.S. Pat. Off.

In the pressroom of a supplier, the back of a military brush is blanked from Formbrite red brass strip.

Empire Brushes, Inc., Port Chester, N. Y. produces an extensive line of military and clothing brushes with Formbrite components. At right, a decorative band is being applied.

Formbrite
is an
ANACONDA PRODUCT
Made by The American Brass Company

42 years of service to industry

DIE CASTINGS by ...

Stewart

... simplify your production problems
... increase your design effectiveness.

A DIVISION OF... STEWART SW WARNER

STEWART DIE CASTING

CHICAGO, ILL., 4535 FULLERTON AVE. ... BRIDGEPORT, CONN. 275 WARREN ST.

Bendix-Skinner

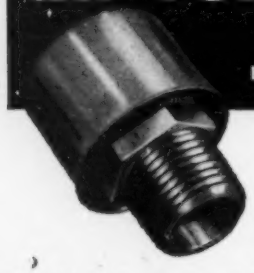
ORIGINATOR OF **MICRONIC** FILTRATION

offers NEW

Ribbon

air vent filters

IN SIZES FOR EVERY APPLICATION

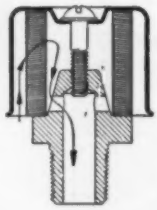


This compact, new ribbon element filter is available *for the first time* in three sizes—¼", ½", ¾" pipe thread, thus meeting the needs of every application.

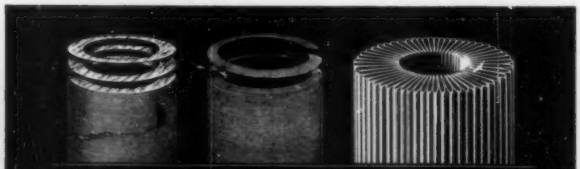
Positive Controlled Filtration. The specially designed element offers *greater efficiency than any air vent filter on the market*—approximately 40 micron filtration (.0016").

Lasts as Long as the Equipment. Although it costs little more than a quart of oil, *this ingenious filter will never wear out* . . . and is easily cleaned.

Hundreds of Uses. The new ***Bendix-Skinner*** Air Vent Filter has literally hundreds of applications. For example, hydraulic systems . . . air compressor intake . . . carburetor intake for small gasoline engines . . . crankcase ventilation . . . pneumatic cylinders . . . fuel tank breather . . . pneumatic instruments . . . immersion or sump filter.



Write Dept. B for complete details on this revolutionary new filter.



SKINNER PURIFIERS DIVISION OF

1503 TROMBLY AVENUE,
DETROIT 11, MICHIGAN

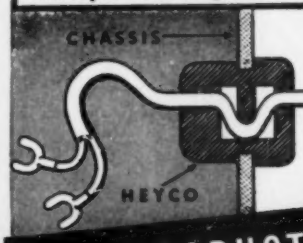
Bendix AVIATION CORPORATION

Export Sales: Bendix International Division, 72 Fifth Ave., N. Y. 11, N. Y.

Facts you should know about

HEYCO STRAIN RELIEFS!

the Nylon Bushings that Anchor cord to housing



1. Absorb cord pull, push and torque
2. Insulate wire from housing

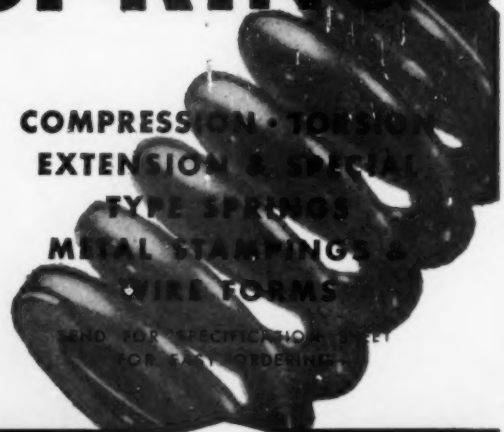
CUT PRODUCTION COSTS
IMPROVE PRODUCT QUALITY

APPROVED SA UL

SAMPLES? Send wire size and chassis information—
Try HEYCOS at no cost to you—today!
MADE IN ALL SIZES FOR CLOCK WIRE TO S-10/3 CABLE

HEYMAN MANUFACTURING COMPANY
KENILWORTH 3 NEW JERSEY

EVANS' SPRINGS



COMPRESSION • TORSION
EXTENSION & SPECIAL
TYPE SPRINGS
METAL STAMPINGS &
WIRE FORMS

SEND FOR SPECIFICATION SHEET
FOR EASY ORDERING

JOHN EVANS' SONS, INC.
506 NORTH 13th STREET
PHILADELPHIA 23, PA.

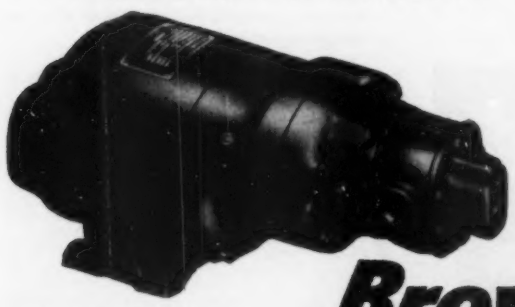
185 Stock Pumps

that make precise selection easy

FOR HYDRAULIC SERVICE, COOLANT, LUBRICATION, AND MISC. INDUSTRIAL USES

Knowledge of the complete line of Brown & Sharpe Pumps can be a valuable asset to you. It will save you time and money on many design jobs calling for smooth, quiet pump operation . . . and extended pump life without maintenance troubles. Most often, you'll find just the pump you need among the 185 stock models . . . centrifugal, geared, reversing vane . . . direct or motor-driven. If a special pump is required, however, you can depend on Brown & Sharpe engineers to design it to meet your requirements.

Complete, illustrated information on each type and size is available in the big Brown & Sharpe Pump Catalog. It includes all data, installation dimensions, and charts showing performance characteristics. Write for your copy. Brown & Sharpe Mfg. Co., Providence 1, R. I., U.S.A.



WE URGE BUYING THROUGH THE DISTRIBUTOR

Brown & Sharpe B·S

LINK UP with ACME CHAIN

ACME Chain takes pride in producing precision engineered roller chains that are functionally efficient . . . to meet each specific application.

These chain drives are simple in design to assure less maintenance. What's more, ACME Chains are all-steel drives to give full rated power . . . smoothly and effortlessly. Their positive grip affords constant, uniform speed . . . without friction loss or slippage. Furthermore, ACME Chains are quickly and easily installed . . . to reduce costly production time. Remember . . . if your machines depend on roller chains, link up with ACME . . . to assure trouble-free operation, peak performance, high level production and low maintenance costs.

If you have any chain drive problems, let ACME engineers with over thirty years' diversified experience in the roller chain industry recommend the right kind of chains for your specific needs. For quick information and service . . . write or phone today.

Write Dept. 1C for new illustrated 76 page catalog on use and application of roller chains and sprockets.

Acme Chain Corporation
HOLYOKE
MASSACHUSETTS

he's working for you

THIS FELLOW IS TRAINED IN YOUR BUSINESS. His main duty is to travel the country — and world — penetrating the plants, laboratories and management councils . . . reporting back to you every significant innovation in technology, selling tactics, management strategy. He functions as your all-seeing, all-hearing, all-reporting business communications system.

THE MAN WE MEAN IS A COMPOSITE of the editorial staff of this magazine. For, obviously, no one individual could ever accomplish such a vast business news job. It's the result of many qualified men of diversified and specialized talents.

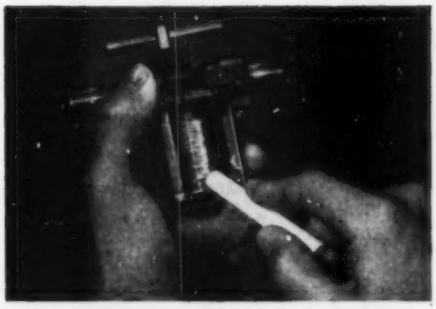
AND, THERE'S ANOTHER SIDE TO THIS "COMPOSITE MAN," another complete news service which complements the editorial section of this magazine — the advertising pages. It's been said that in a business publication the editorial pages tell "how they do it" — "they" being all the industry's front line of innovators and improvers—and the advertising pages tell "with what." Each issue unfolds an industrial exposition before you — giving a ready panorama of up-to-date tools, materials, equipment.

SUCH A "MAN" IS ON YOUR PAYROLL. Be sure to "listen" regularly and carefully to the practical business information he gathers.

McGRAW-HILL PUBLICATIONS

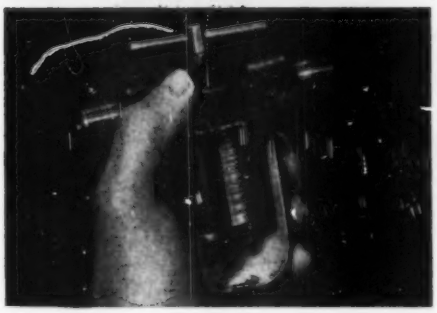
Here's how this strainer "combs" itself clean!

This simple chalk test shows how AUTO-KLEAN's unique built-in comb construction cleans the strainer without costly interruption of flow



ORDINARY BLACKBOARD CHALK leaves heavy deposit of chalk particles on and between discs of Cuno AUTO-KLEAN strainer.

TURNING HANDLE ONE REVOLUTION moves strainer element through comb blades, removing all traces of chalk from between discs. Cuno's exclusive combing operation cleans *thoroughly* —without stopping flow.



FILTERING AREA IS COMPLETELY CLEAN, restoring full initial capacity. All chalk particles and dirt fall to bottom of housing where they can be drained periodically.

- AUTO-KLEAN's permanent metal filter element is available in steel, brass, or stainless steel for long, trouble-free service.
- AUTO-KLEAN is adaptable to any fluid-flow system.
- From acids to tar . . . if you can pump it, Cuno can filter it. Capacities range from one gallon per hour to 15,000 gallons per minute.

CUNO ENGINEERED FILTRATION

Removes More Sizes of Solids from More Kinds of Fluids

AUTO-KLEAN (disc-type) • MICRO-KLEAN (fibre cartridge) • FLO-KLEAN (wire-wound)

SINGLE-STRAINER FLUID PROTECTION ...WITH AUTO-KLEAN

Continuously cleanable AUTO-KLEAN eliminates need for stand-by strainers

Design engineers everywhere are increasing their products' sales potential by incorporating streamlined AUTO-KLEAN strainers in their new products. Here are some of the reasons why:

1. The low pressure drop operation of the AUTO-KLEAN allows *full-flow* service on gravity, low pressure, high pressure or suction lines—with no loss in operating efficiency. AUTO-KLEAN's compact construction provides this continuous, full-flow protection in space which would limit ordinary filters to by-pass service.

2. Cuno's exclusive "comb-clean" action provides complete cleaning of the filter element—*without stopping fluid flow.* Thus, there's no need for providing a stand-by strainer.

3. AUTO-KLEAN's fixed-space metal discs will remove all solids larger than the specified disc spacing—from .0035" up to .062".

4. AUTO-KLEAN's all-metal filter element is *permanent*—lasts as long as the machine on which it's installed.

Follow the lead of the big names in industry and build AUTO-KLEAN into your equipment—it's good design, and good business. Write now for more information.

A.3.8

Cuno Engineering Corporation
Dept. 308A South Vine Street, Meriden, Conn.

Please send me free bulletin on Cuno AUTO-KLEAN for .....
(fluid)

Name.....

Company.....

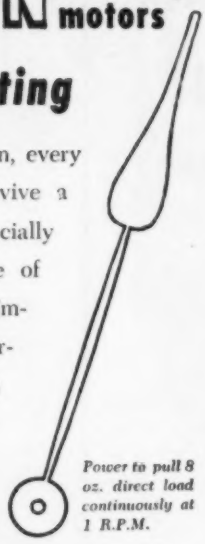
Address.....

City.....Zone....State.....

SYNCHRON® timing motors

for instant starting

Before it passes final inspection, every SYNCHRON motor must survive a rigid operating test on a specially designed block to make sure of instant response to current impulse. No guesswork is tolerated! You can depend upon SYNCHRON for instant starting, with full power delivery.



Power to pull 8 oz. direct load continuously at 1 R.P.M.

Operates efficiently in any position, and at −40° to +140° F.

easily adapted

to standard timing devices. Gear trains can be furnished to convert to any desired speed and unusual actions can be incorporated. Special timing problems are given special attention by SYNCHRON engineers.

timing machines

Powered by dependable SYNCHRON motors. Complete . . . ready to install in any timing device.

Mail coupon for engineering data

HANSEN MANUFACTURING CO., INC., Princeton 5, Ind.

Send catalog and engineering data to:

Name .....

Firm .....

Address .....

City .....Zone .....State.....

LOW COST BOOST PUMP

Air operated hydraulic boost pump capable of output fluid pressures to 50,000 PSI. from 100 to 150 PSI. plant air supply.

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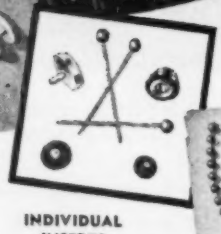

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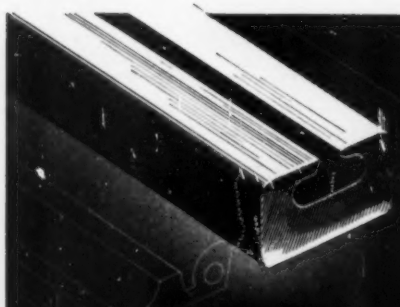

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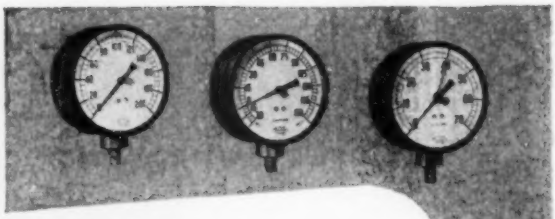

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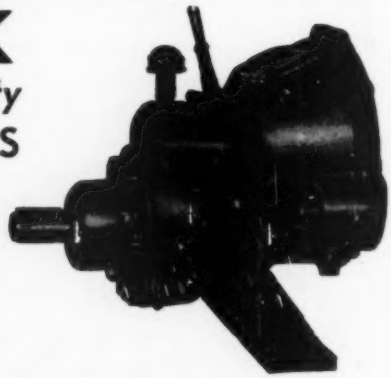

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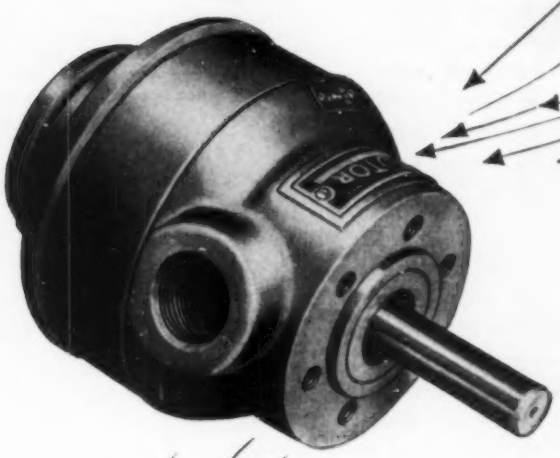

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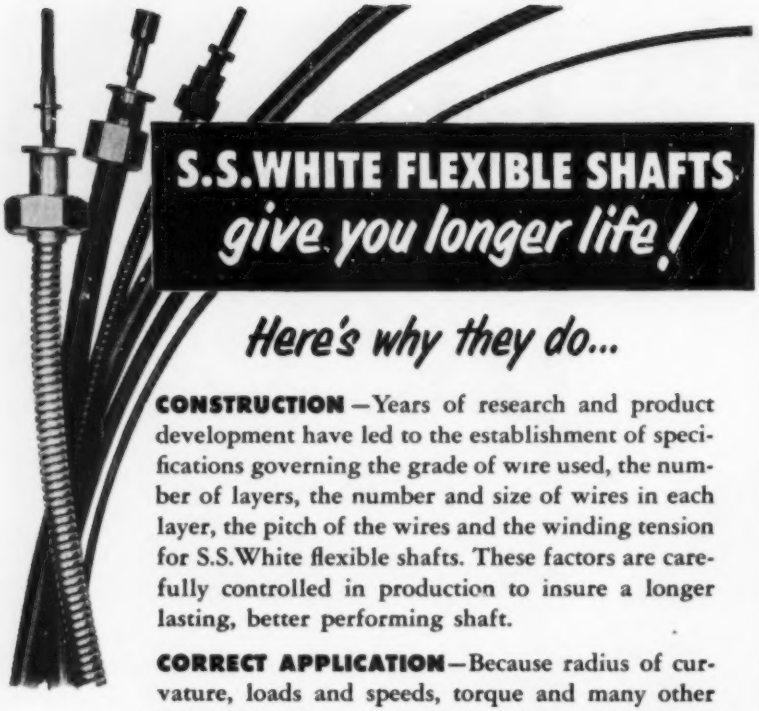

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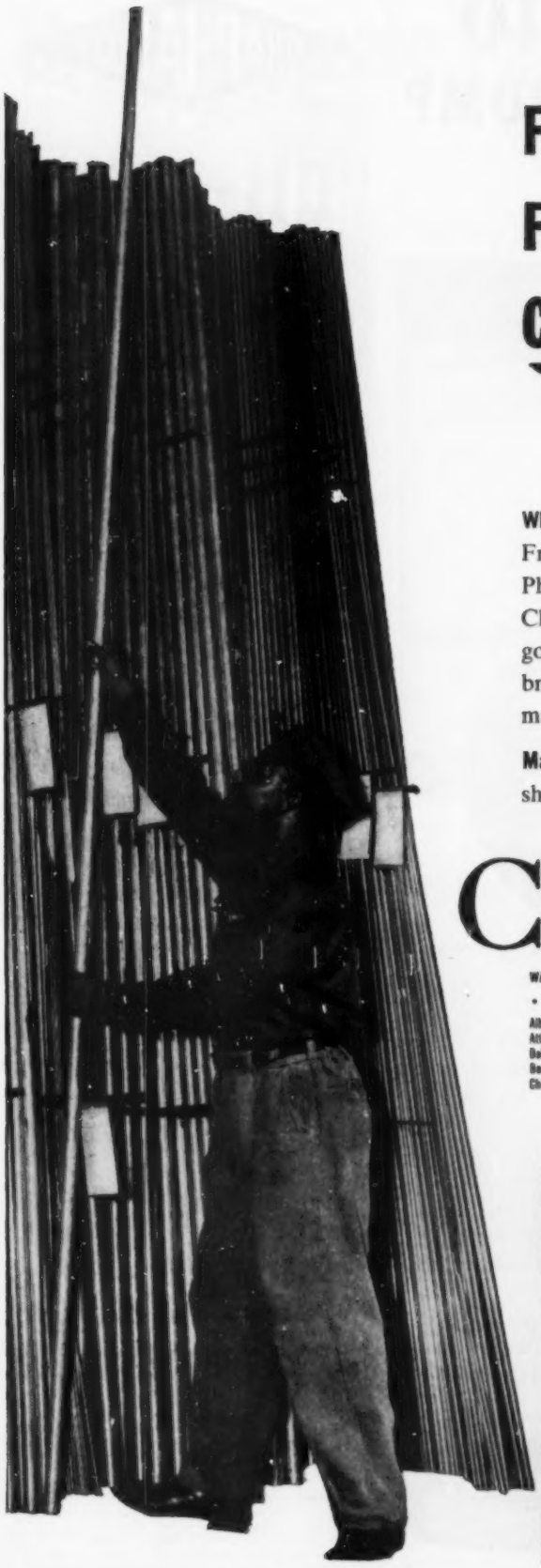

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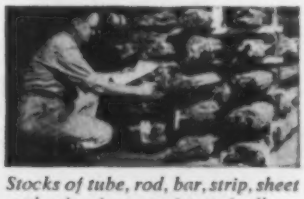

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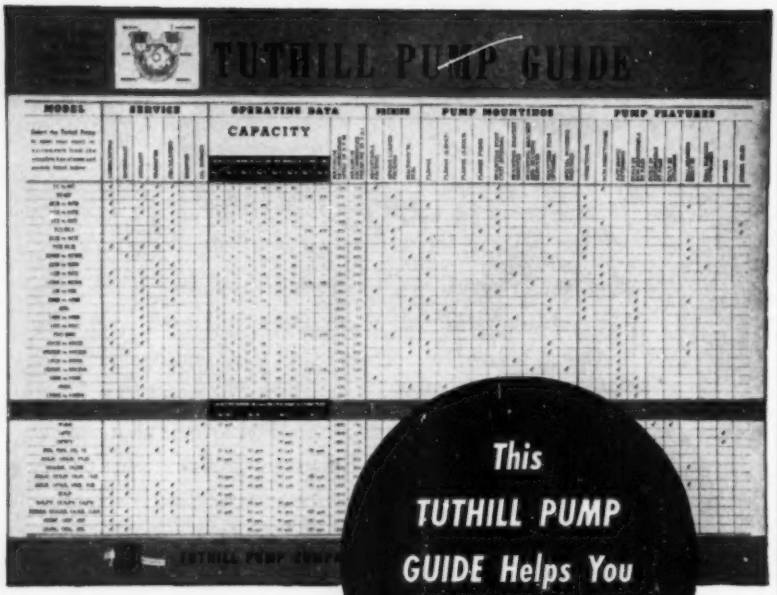

This TUTHILL PUMP GUIDE Helps You Find the Answer

To save you time and trouble in selecting the pump best-suited to your application, Tuthill engineers have developed this revolutionary new Pump Guide. Here, in one easy-to-use chart, is a volume-full of information on the complete line of Tuthill Pumps.

At a glance, it shows you the services for which each model is built, together with performance characteristics, types of packing, mounting styles and distinctive features that enable you to fit the pump to your need, rather than the need to the pump.

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ECONOMICALLY TO CLOSE DIMENSIONS

Housing for Rod Feeder

Internal Operating Lever

These two parts—vital to a starting-rod feeder for a hand-scarfing blowpipe—are produced in quantity by HAYNES precision-investment casting. Both parts are too intricate in shape for accurate production by conventional casting methods. And since they are made from stainless steel, the cost of machining the parts in quantity would be prohibitive.

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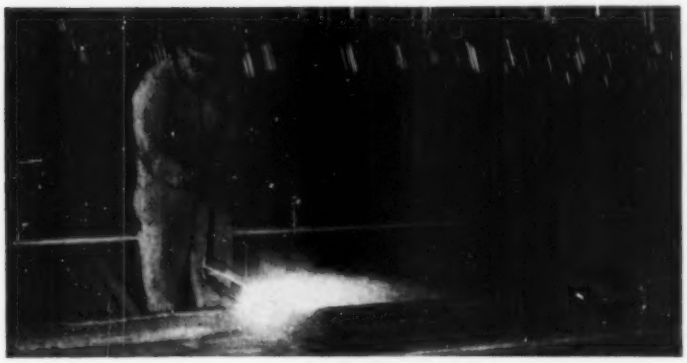

The efficiency of the starting-rod feeder on this hand-scarfing blowpipe is partly due to the use of HAYNES *investment castings for the critical parts of the assembly.*

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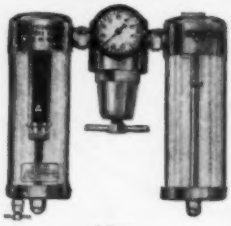

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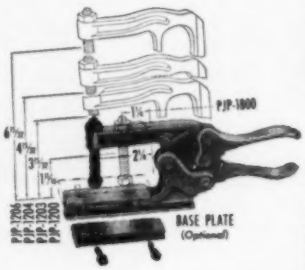

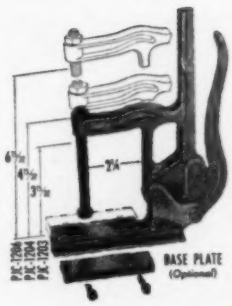

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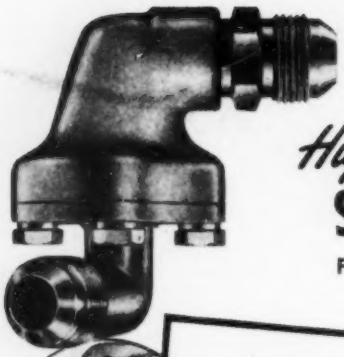

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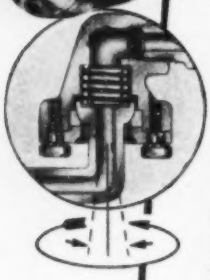

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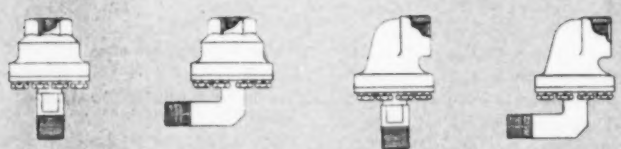

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Many Important Sales Advantages Displayed in Popular Aluminum Tension Screens

Simple installation, easy operation, long life and comparatively low cost are prime features of the aluminum tension screens made by the Ry-Lock Company Ltd., of San Leandro, California. These builder and owner advantages are heightened by the use of rustproof, rotproof, always attractive aluminum in both screens and screen framing.

Ry-Lock, the first aluminum tension screen manufacturer in the country, uses Reynolds Aluminum exclusively in their quality line of tension screens for wood and metal windows of all types. Clingan and Fortier, Inc., one of the Reynolds Distributors in Los Angeles and San Francisco, serves the Ry-Lock Company with aluminum for screen bars and hardware fittings.

Ry-Lock Tension Screen installed on casement window.

The aluminum construction gives Ry-Lock sales advantages not provided by other materials. There is nothing to rot or warp. Aluminum does not require painting yet blends with any color scheme. Furthermore, users can be assured that surfaces adjoining the aluminum screens will not be streaked with rust or corrosion stains.

Tension screens manufactured and distributed under the "Ry-Lock" name in the eleven Western states are a product of the Ry-Lock Company. The New York Wire Cloth Company has been licensed to manufacture and distribute them in the other thirty-seven states under the name "Durall."

For a free copy of Reynolds 1953 Product Design catalog, and a complete index of technical literature and movies, write to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

Behlen Manufacturing Company Opens Broad New Fields In Modern Building Design and Construction

Fourteen tractors, weighing 32 tons, suspended from roof ridge of frameless Behlen aluminum building. Insets show alternate methods of eave construction.

Ample proof of what you can accomplish with aluminum and good design, is found in the popular frameless aluminum buildings produced by the Behlen Manufacturing Company of Columbus, Nebraska.

Designed primarily for industrial, farm and military use, these straight side, frameless Behlen buildings are constructed without upright support members for walls or in the interior, and without truss support for the gable-type roof.

Deeply corrugated aluminum panels for walls and roofs are bolted together at the eaves and roof ridge to form a continuous arch. The arch sections are in turn bolted to each other to form a complete, weatherproof, load-bearing shell.

Panels for the Behlen buildings are made from .064-inch to .072-inch aluminum alloy sheets, corrugated to a depth of 7½ inches. This corrugating adds so much rigidity that each arch section has the same strength as an I beam of equivalent weight.

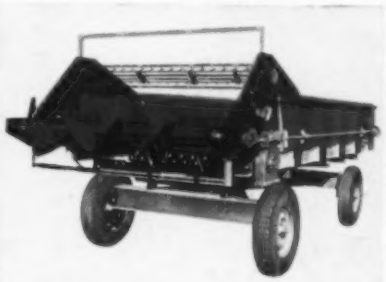
All of the important advantages of strong, light weight, rust-proof, heat reflecting, maintenance-free aluminum are utilized to the maximum by progressive Behlen engineers. To get similar advantages in your products, have a Reynolds Aluminum Specialist assist you on new or redesign problems.

Reynolds Aluminum Specialists will be glad to work with you, just as they have worked with Behlen and countless other companies. This assistance is yours without obligation through the Reynolds office or Reynolds Distributor listed under "Aluminum" in your classified telephone directory. Or write direct to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

Rustproof, Acid Resistant Aluminum Plays Important Role in Manure Spreader

In this efficient combination of power box and manure spreader, the rustproof and corrosion resistant advantages of aluminum are used to withstand manure acids.

The Farmhand Power-Box sits on truck, wagon or trailer with equal ease. When connected to a source of power, the bed of the



box moves the load back to a Farmhand Spreader Attachment for the final flip that distributes manure evenly over the field.

Because of the corrosive action of manure, both pieces of equipment are made primarily of aluminum and treated wood. They are manufactured by The Farmhand Company, a division of Superior Separator Company, Hopkins, Minnesota.

MORE INTERESTING NEWS ABOUT ALUMINUM ON NEXT PAGE

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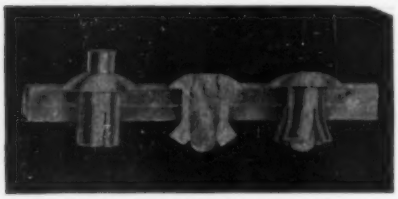
(Continued From Preceding Page)

Aluminum Drive Rivets Save Production Time and Money

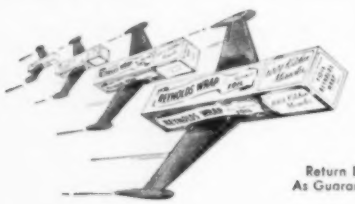
Aluminum rivets, nuts, bolts, screw, washer, cotter-pins and other mechanical fasteners are produced by a number of leading manufacturers who rely on Reynolds for top quality material. A typical example, is the aluminum Southco Drive Rivet, one of several aluminum fastening devices made by the South Chester Corporation of Lester, Pennsylvania.



The photograph illustrates how a hammer-driven pin expands the prongs of this patented rivet, drawing panels together in a tight, secure joint. Thus blind joints made with aluminum Southco Drive Rivets are quickly and easily completed. There's no bucking, trimming or grinding. Once driven, the inserted grooved pin cannot work loose even under severe vibration.

Use of rustproof and corrosion-resistant aluminum fasteners with aluminum assemblies prevents any possibility of galvanic reaction between dissimilar metals when they may be subjected to moisture or water.

For your free copy of the valuable handbook "Fastening Methods for Aluminum," plus a complete index of Reynolds technical literature, write on your business letterhead (otherwise the book is $1.00) to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.



Return Flight As Guaranteed

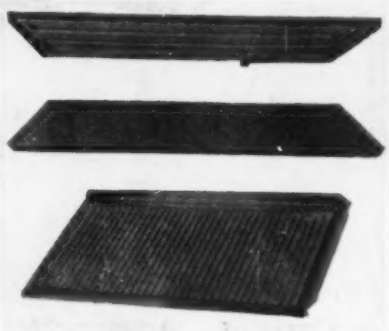
Reynolds Aluminum Foil Now Used As Facing for Glass Fiber Insulation

Gustin-Bacon Manufacturing Company, makers of Ultralite and Ultrafine glass fiber insulations, now offers this material faced with Reynolds Aluminum foil . . . another example of the fast growing list of applications for aluminum foil in many industries.

Growing Industries Rely on Reynolds Aluminum Fabricating Service

More and more companies in diversified industries are taking advantage of Reynolds complete fabricating service for aluminum parts. As an example, illustrated below are two types of aluminum shelving produced by Reynolds Parts Division for the refrigeration industry.

Vertical freezer shelves are made from Reynolds high strength aluminum alloy sheet to which aluminum tubing is cleanly and securely brazed. These shelves provide a high degree of heat transfer efficiency in addition to being rigid and durable. They are available with a plain anodized or Alodized finish. One-



piece, Reynolds Aluminum refrigerator shelving, with a corrosion-proof and chip-proof plain or color anodized finish, is also rigid and attractive.

Whether you want final assemblies, completed parts, blanks or roll-formed shapes, you'll find the extensive facilities and technical assistance of Reynolds Parts Division real value. Contact the nearby Reynolds office listed under "Aluminum" in your classified telephone directory or write Reynolds Metals Company, Parts Division, 2065 South Ninth Street, Louisville 1, Kentucky.

A one-half inch thick pad of the glass fiber with .0007-inch aluminum foil is commonly used as a furnace jacket liner. The radiant heat reflecting surface of the foil, plus the pad of insulation, keeps the jackets cooler and reduces popping noises due to the contraction and expansion of the casing. Leading manufacturers of furnaces are using more and more aluminum foil faced Ultralite and Ultrafine for this purpose.

Air conditioning ductwork insulated with foil faced Ultralite

Ultralite faced with .0025-inch aluminum foil also provides a complete vapor barrier in the insulating of air conditioning ducts. The aluminum foil barrier prevents condensation from forming on the cold duct surface or in the bulk insulation. And since aluminum, Ultralite and Ultrafine are all fire-resistant, this insulation passes city building codes. The .0025-inch foil faced Ultralite is also used extensively in the insulation of metal buildings.

The Gustin-Bacon Manufacturing Company has its general offices in Kansas City, Missouri, and maintains branch offices and distributors in a number of large cities.

For information on the application of Reynolds Aluminum foil in your products write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

It's Sno' Fun Without A Light, Aluminum Shovel!

Here's tomorrow's weather forecast: SNOW—followed by little boys on sleds . . . and big fellows with snow shovels.

You can cut down on those backaches, however, if you have a featherweight aluminum snow shovel like the one illustrated here, that's made by the Hamlin Metals Products Company of Akron, Ohio.

Hamlin, like other manufacturers of quality products, relies on Reynolds Aluminum to add dependability plus sales appeal to their snow shovels. They make the light weight, rust-free blades with a Reynolds hard aluminum alloy.

Remember—whether you are designing or manufacturing anything from snow shovels to steam shovels, Reynolds Aluminum Specialists are ready to help you get the most from aluminum. Call your Reynolds office listed under "Aluminum" in your classified telephone directory or write Reynolds Metals Company, 2576 S. Third St., Louisville 1, Ky.

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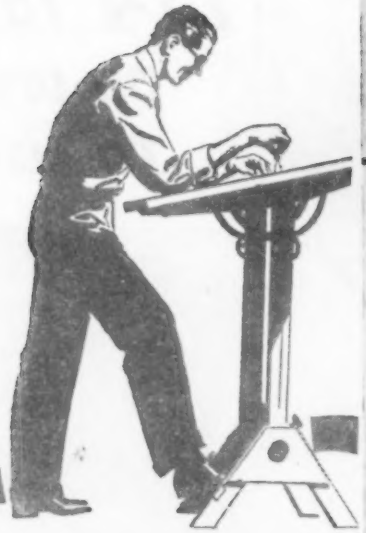

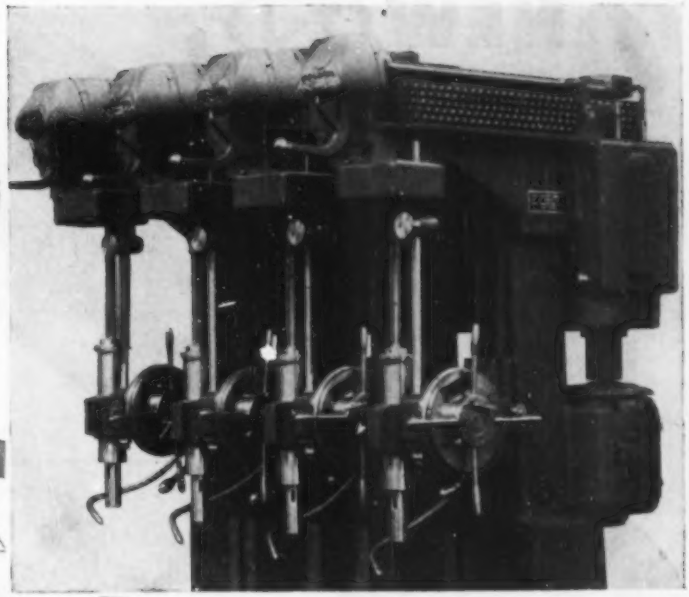

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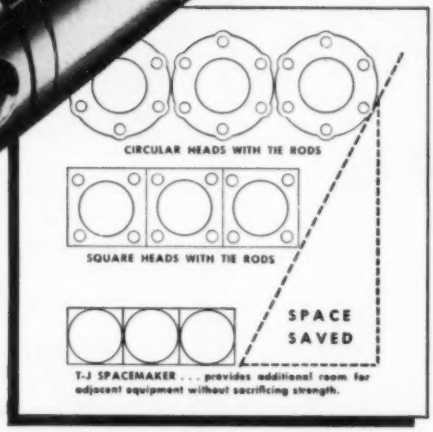

T-J SPACEMAKER . . . provides additional room for adjacent equipment without sacrificing strength.

- SAVES UP TO 40% SPACE WITH NEW STREAMLINED DESIGN.
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- HEAVY DUTY, HI- TENSILE, HARD CHROME PLATED PISTON ROD.

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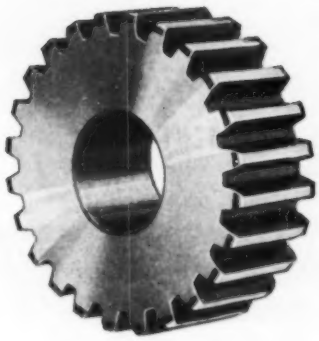

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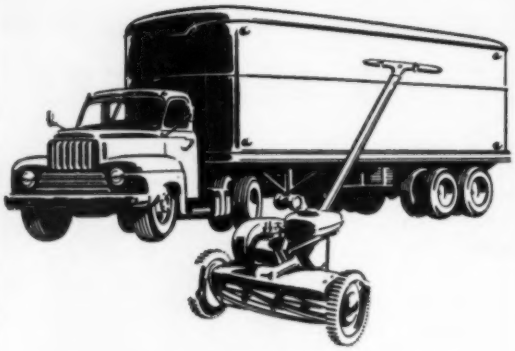

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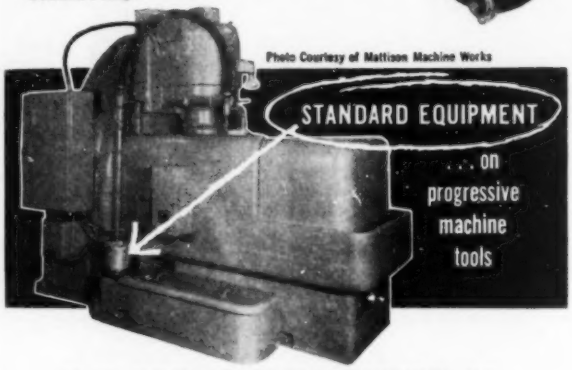

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Cellular structure reduces the need for large quantities of expensive silicone and rubber, yet maintains the properties important to users ot silicone rubber.

Check your use ot silicone rubber—maybe we can help you cut costs. Write us at the address below for further information.

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Because even the best and most attractive product will sell better when it is attractively and eye-catchingly labeled, design engineers are increasingly aware of the importance of attractive nameplates escutcheons, and instruction plates. All can be accentuated by proper treatment to give your product increased brand recognition and sales appeal.

This comprehensive report on contemporary methods and processes for better product identification, "Identifying Your Product," is one of *Product Engineering's* series of full-color articles covering product improvement through better surface appearance, protection, and identification.

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DEPENDABLE PERFORMANCE calls for STOW

Picture courtesy BROOME G. L. F. ELEVATOR

G.L.F. depends on STOW flexible shafting for speedy grain delivery!

"Since installing STOW flexible shafting on our bulk feed delivery units, we have lost no time due to breakdowns and have had no maintenance problems in over five months of continuous service", says Mr. Joseph Collins, manager, Broome G.L.F. Elevator.

This STOW flexible shaft application replaces a universal joint series which would not stand up under the rugged conditions to which it was subject during deliveries to farms. Primary cause of the failure, according to Mr. Collins, was the steep angles through which the universal joints had to operate. Prior to the installation of STOW flexible shafting, Broome G.L.F.'s grain delivery units suffered frequent breakdowns, each of which involved three or four-hour delays and upped delivery costs.

This is another excellent example proving the efficiency, the practicability of STOW flexible shafting. Why not consult with STOW engineers on *your* next power transmission problem?

WRITE TODAY for your FREE Torque Calculator and Bulletin 525 containing complete data on STOW flexible shafting. No obligation, of course.

STOW

FIRST IN FLEXIBLE SHAFTING SINCE 1885

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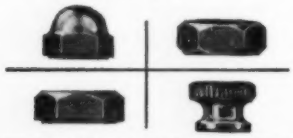
are checked by gage

You won't lose your temper over off-tolerance if you order "Fischer Turned" Brass Nuts for your products. All Fischer nuts are carefully gaged from rod to finished precision product. Fischer guarantees you that every order will meet your specs.



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By dealing direct with Fischer you free yourself from high blood pressure and high prices . . . *you get the highest quality nut at the price of common punched nuts.* We'll be glad to prove that promise with samples and quotations. *Send today!*

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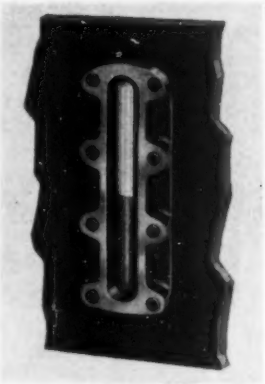

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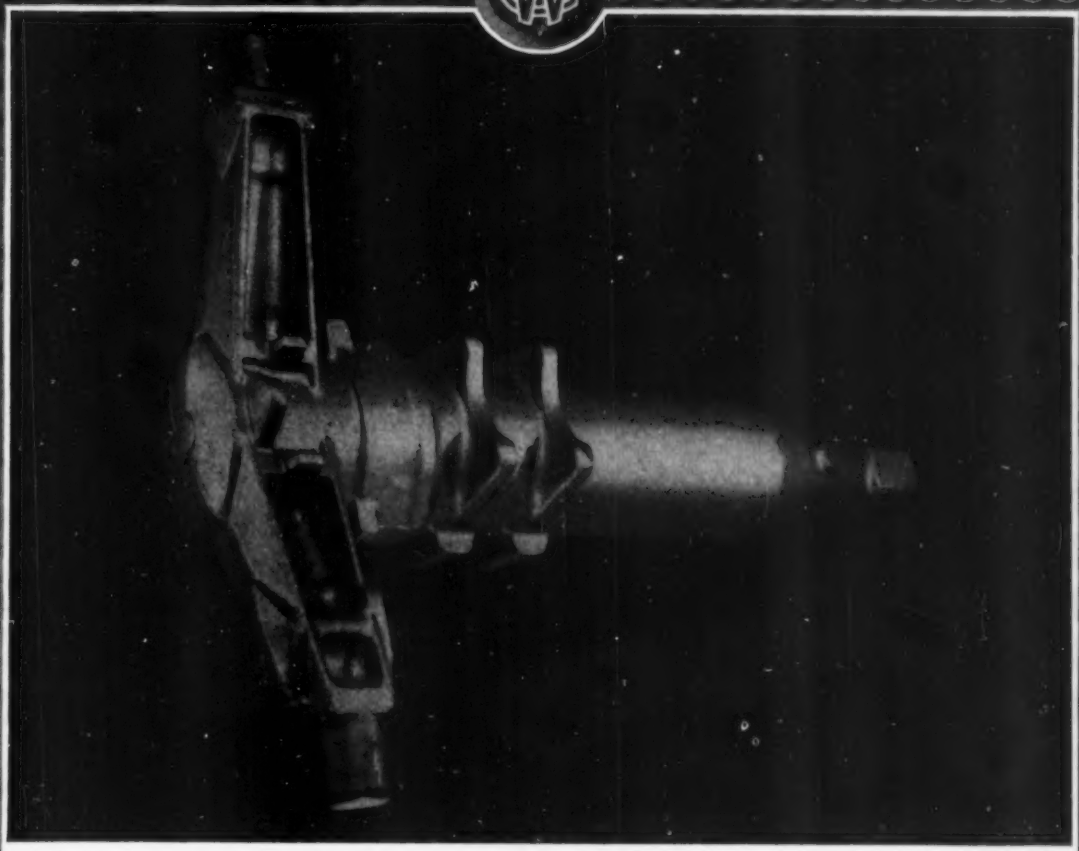

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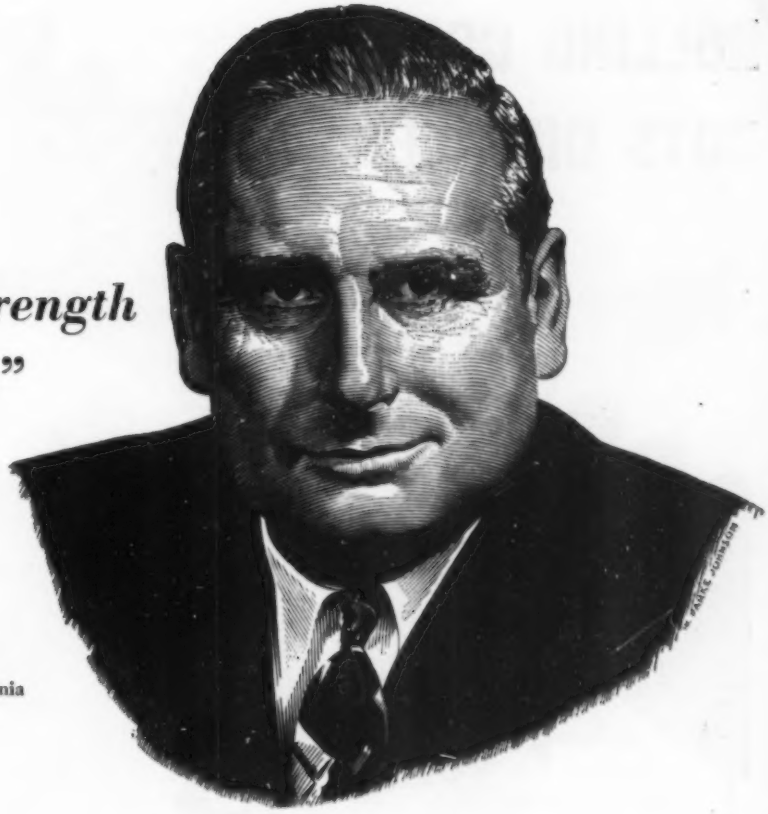

REESE H. TAYLOR
President, Union Oil Company of California

"Our country's strength is created by the responsibility and solidarity of individual citizens in a self-chosen government and economy. It can—and must—be perpetuated against all who seek to undermine it. The men and women who invest regularly in United States Defense Bonds are contributing to our national integrity and to the traditions of personal independence so characteristic of a free people."

Every pay day, 6,500,000 employed men and women . . . "are contributing to our national integrity and to the tradition of personal independence . . ." by the systematic purchase of United States Defense Bonds.

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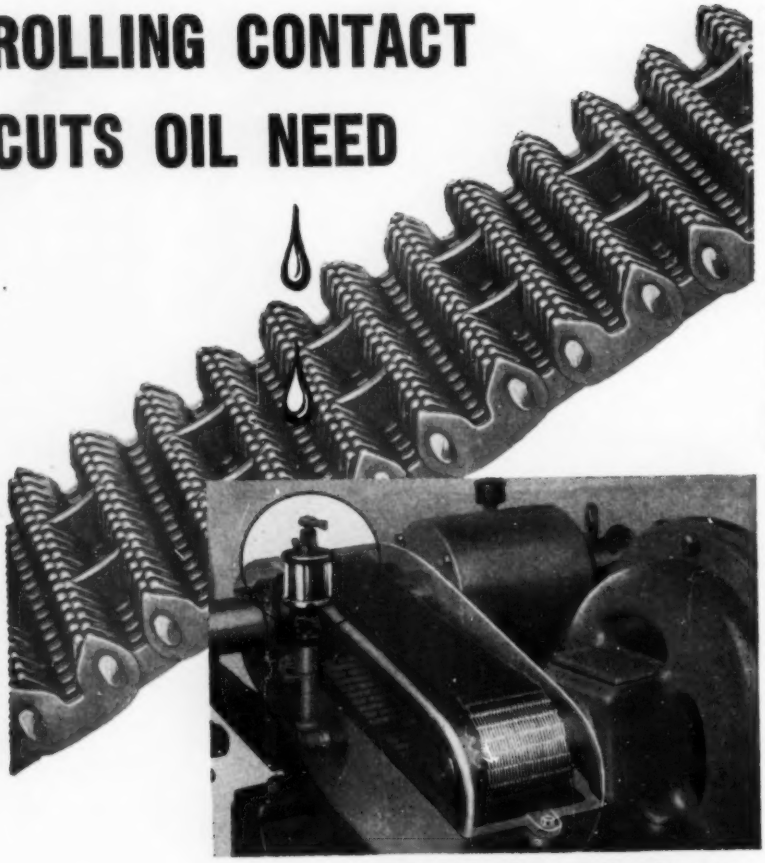

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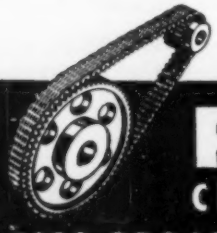

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AT YOUR FINGER TIPS, issue after issue, is one of your richest veins of job information—advertising. You might call it the "with what" type—which dovetails the "how" of the editorial pages. Easy to read, talking your language, geared specifically to the betterment of your business, this is the kind of practical data which may well help you do a job quicker, better—save your company money.

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You, too, have a big stake in the advertising pages. Read them regularly, carefully to keep job-informed on the "with what" part of your business.

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Powered to win any race with disaster . . . utterly reliable for mercy missions over treacherous waters . . . the 1425-h.p. engine for air-sea triphibians is a marvel of modern precision engineering. To help swell volume production of this Wright Cyclone engine, Curtiss-Wright and the U. S. Air Force rely on the skill and resourcefulness of Lycoming.

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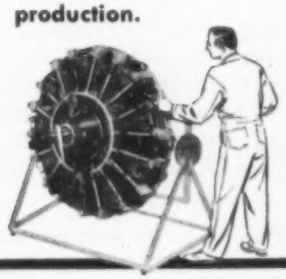

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Fabricated

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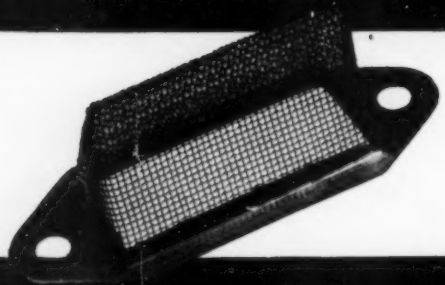
***Available** — a well-equipped plant with highly experienced fabricators.



***Available** — mesh cloth and space cloth made in our own plant.

All under one roof

Do you require parts made with one or more pieces of mesh cloth or space cloth — anything from 4 inch openings down to 325 mesh (105,625 holes/sq. in.)?

Our experienced fabricating service should be of value. We are in position to handle volume order business and, if desired, will be glad to help in designing the part requiring the metallic cloth. We know how to insert and fasten metallic cloth to get best results. We carry many standard sizes of wire cloth in stock. We have ample loom facilities to weave special cloths if necessary. We can handle any wire of any malleable metal.

This fabricated parts division of our business has grown by leaps and bounds. We have had many repeat orders. It could be due to the quality of wire cloth used and the care with which this cloth is assembled into the parts being fabricated.

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MATERIALS
SUB-ASSEMBLIES
or
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Chances are you will always find in **Product Engineering's** "New Catalogs and Bulletins" insert several listings offering literature which will supplement the articles and advertisements which are of greatest interest to you.

So, each month, be sure to check through the "New Catalogs and Bulletins" and send us your requests. Without cost to you, we'll see to it that the manufacturers concerned receive your requests promptly.

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Product Engineering

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WHICH sleeve bearing would you use?

THERE ARE many things to consider when selecting a Sleeve Bearing. Johnson engineers appraise service conditions carefully: load, shock, speed, temperature, lubrication, corrosive conditions and other service considerations. Based on these studies, they will recommend the Sleeve Bearing to suit the application. Since Johnson Bronze produces bearings from cast bronze, cast aluminum alloy, sheet bronze, bronze on steel, babbitt on steel, babbitt on bronze, powdered metal and graphited bronze, a wide variety of Sleeve Bearings is available, and can be recommended without prejudice to any one type. If you are in doubt about the bearing to specify, ask Johnson Engineers. No obligation. Write today.

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508 South Mill St., New Castle, Pa.

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SLEEVE BEARING HEADQUARTERS SINCE 1901

SUPERDRAULIC

PUMPS • VALVES • TRANSMISSIONS • TEST STANDS • REMOTE CONTROLS

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Superdraulic Corporation is a nationally recognized complete facility capable of performing all details from design to complete fabrication of hydraulic machines and equipment. Many important manufacturers have found it practical to consult with our engineers on projects at inception and benefit by the extensive experience of this organization. Important short cuts and simplified processes may be revealed to you by such coordinated effort.

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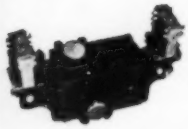
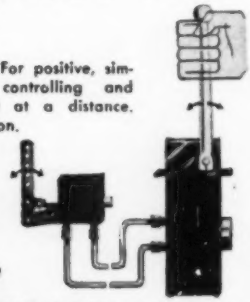
CONTROLS. To meet all operating requirements: adjustable, fixed pressure, pressure reduction, proportional pressure, sequence operation. Also check valves and specials.



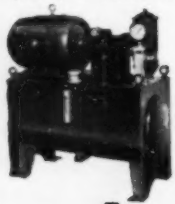
VALVES. 4-way sliding spool type in a complete series including solenoid control pilot operated, pilot operated and manual.



REMOTE CONTROL. For positive, simplified positioning, controlling and duplicating movement at a distance. Installs in any position.

TEST STANDS. Include: pumps, valves, reservoirs, motors, flexible couplings, piping and cabinets. Units developed up to 30,000 PSI

POWER UNITS. Complete including pumps, relief valves, reservoirs, electric motors, piping, and valving to meet requirements.



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For use in Neon Sign Transformers, one piece fits inside transformer case, other piece fits outside case, forming a perfect insulator.

• Porcelain Insulators, properly engineered and applied, add high dielectric and physical strength. In Universal Porcelain Insulators, you gain this extra protection . . . *plus* higher resistance to temperature changes, moisture, fumes and most acids. On your next insulator job, specify Universal Porcelain.

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THIS BOOK . . . will answer all your BRONZE CASTING PROBLEMS

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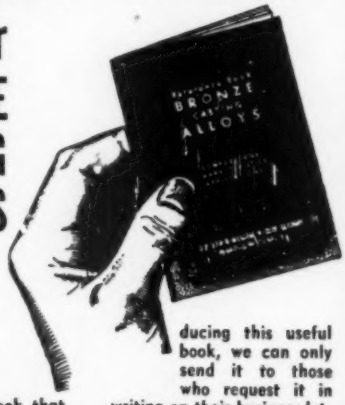

A 46-page, flat-opening, flexible-bound Reference Book that should be in the hands of every Engineer who specifies or uses Bronzes. Due to the cost of preparing and producing this useful book, we can only send it to those who request it in writing on their business letterheads — and remember, there's over 43 years "specialized experience" in casting Bronzes behind us.

AMERICAN MANGANESE BRONZE COMPANY

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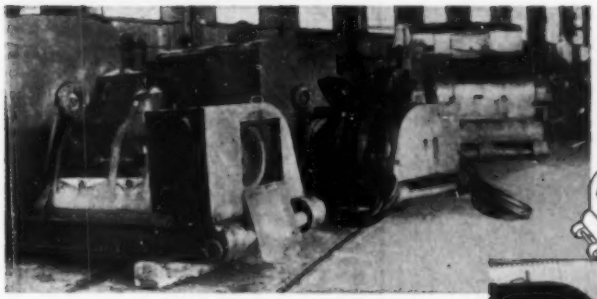
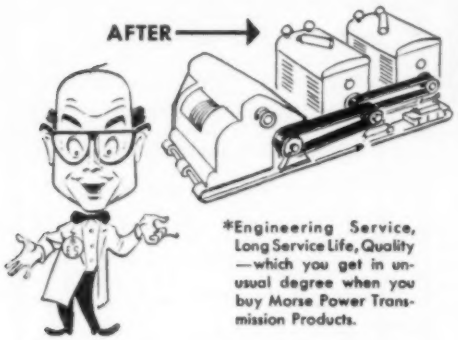
Established 1909



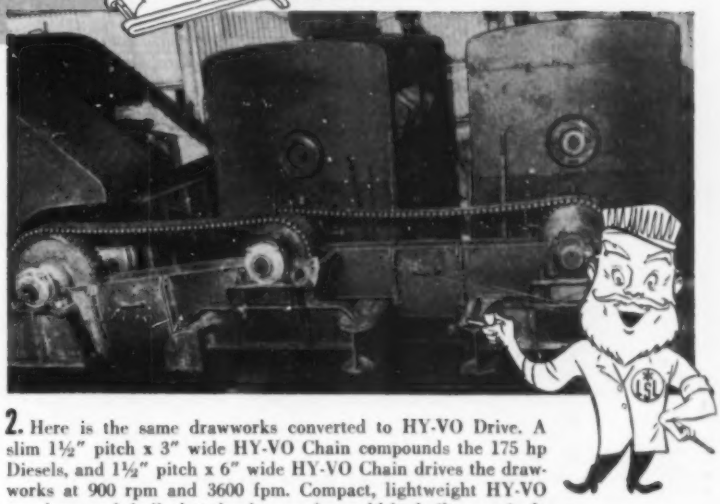
BEFORE

1. This rig with compound Diesel engine and drawworks had to be built in three parts because of huge bulk of V-belt drives. Assembly, disassembly and "trueing up" wasted time, money. Also, drive tension needed when drilling below 8000 feet caused bearing failures seven times in one year.

AFTER



*Engineering Service, Long Service Life, Quality —which you get in unusual degree when you buy Morse Power Transmission Products.



2. Here is the same drawworks converted to HY-VO Drive. A slim 1½" pitch x 3" wide HY-VO Chain compounds the 175 hp Diesels, and 1½" pitch x 6" wide HY-VO Chain drives the drawworks at 900 rpm and 3600 fpm. Compact, lightweight HY-VO saved so much bulk that the drawworks could be built as a single unit, easily hauled on one truck. Too, extra capacity of HY-VO allows deep drilling *with no undue strain* on bearings.

Put these Morse design advantages to work for you

You get results as remarkable as those outlined above when you put the design advantages of Morse Power Transmission Products to work for you.

In the high-speed, heavy-duty field, for instance, a single, compact HY-VO Drive transmits up to 5000 hp, at speeds up to 3600 rpm, and at linear velocities up to 6500 fpm. HY-VO cuts costs 50%, gives one-third longer service life.

Or perhaps you could use lubrication-free Morse Morflex or Morflex Radial Couplings; heavy-duty, small-diameter Pullmore Clutches; or Morse Roller Chains and Silent Chains with their extra-long service life, 99%-plus efficiency.

We'll be glad to offer consultation services on any Morse product application you have in mind (see listing below). Write for information today.

For design advantages in your products, specify Morse equipment:

CHAINS
HY-VO Drives, Roller Chain Drives, Silent Chain Drives, Cable Chains

CLUTCHES
Morse-Rockford Over-Center Clutches, Pullmore Multiple Disc Clutches

COUPLINGS
Morflex Flexible Couplings, Morflex Radial Couplings, DRC Roller Chain Couplings, DSC Silent Chain Couplings

SPROCKETS
Roller Chain Sprockets, Silent Chain Sprockets

M=PT
Morse *means* Power Transmission

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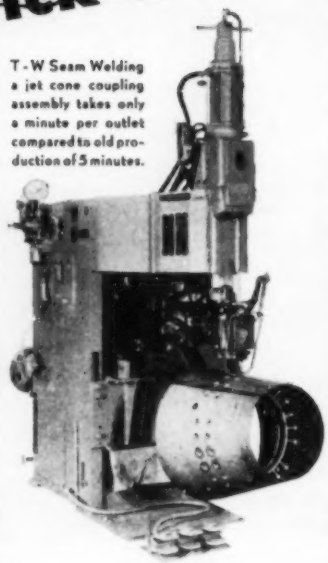

T-W Seam Welding a jet cone coupling assembly takes only a minute per outlet compared to old production of 5 minutes.

Any one of them uses T-W Resistance Welders to meet Military Specs

● Users of T-W resistance welders have been meeting military specs for some 12 years. When you meet up with the current specifications Mil-W-6860 and 6858 (formerly AN-W-30 and 32), take advantage of this experience. Whether your job is ordnance, aircraft parts, radar, or what have you—you can meet military specifications with TW welders.

Call on Taylor-Winfield for counsel and assistance on your production. All sizes and styles of resistance welders.

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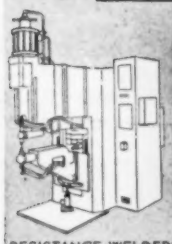
WARREN, OHIO
Sales and Service in All Principal Cities



RESISTANCE WELDERS SINCE 1898

TW TAYLOR-WINFIELD
RESISTANCE WELDERS

HOW TO PLAN PRODUCT COLORS

8 pages—20 cents a copy

Howard Ketcham, well-known industrial designer, has developed color and design themes for over 500 products and packaged items ranging from household appliances to locomotives. In this *Product Engineering* report he discusses the principal factors involved in matching color with product function, sales and advertising appeal, maintenance considerations, worker efficiency, safety, and size effect.

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Individual Spaces with border rules for prominent display of advertisements.

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Index of

PRODUCTS ADVERTISED

In This Issue

•

MATERIALS

Adhesives 80
Aluminum Alloys 64, 85, 237, 323 336-337, 361-362
Beryllium Alloys 375
Bimetal 64, 109, 271
Brass 91, 237, 335, 343-344
Brazing Alloys 259
Bronze 307, 335, 379, 380
Carbon 340
Carbon Graphite 20-21, 31, 356
Ceramics 380
Chemicals 8, 86
Copper Alloys ..2, 64, 91, 109, 307 335, 375
Felt 393
Friction Materials 51, 294-295 322
Glass 94
Graphite 340
Laminated Metals 64, 103, 258
Leather 216
Light Metals 326
Manganese Alloys 380
Molybdenum Alloys 364
Nickel Alloys 60, 107, 320
Nylon 388
Phosphor Bronze 93
Plastics 71, 75, 82, 87, 236, 255 260, 300
Plastics, Laminated 114
Platinum Alloys 64
Powdered Metals ...20-21, 31, 109 239, 356
Rubber & Synthetics 8, 75, 82 216, 260, 298, 352, 358, 369
Silicones 57, 202, 298, 369
Silver Alloys 64
Stainless Steel .....2nd Cover, 14 67-70, 206, 320, 339, 357
Steel ...10, 55, 67-70, 103, 206, 305
Tin 333
Tool Steel 67-70

STRUCTURAL PARTS

Bars 2, 67-70, 305, 320, 375
Bushings 340
Castings 36, 243, 266, 292, 301 302, 306, 312, 323, 357, 380, 394
Coils 245
Die Castings 98, 102, 204, 306 345, 350
Extrusions 75, 85, 352, 361, 362
Forgings 72, 237, 301, 327, 332 373, 380
Metal Powder Parts..20-21, 31, 109 239, 294-295, 340, 356
Perforated Metal 374
Plates 67-70
Rods 307, 361-362, 375, 388
Shapes 67-70, 307
Sheets 67-70, 85, 93, 352 361-362
Stampings 85, 270, 328
Strips 67-70, 105, 335 352, 375, 388
Tubing ...14, 55, 63, 67-70, 85, 99 100, 106, 215, 277, 307, 352, 388
Wire 67-70, 83, 375

FINISHES

Galvanizing 286
Paints & Lacquers....15, 256, 316
Plating 330
Rust Proofing 84, 256, 286, 330
Sealants 267

(Continued on Page 386)

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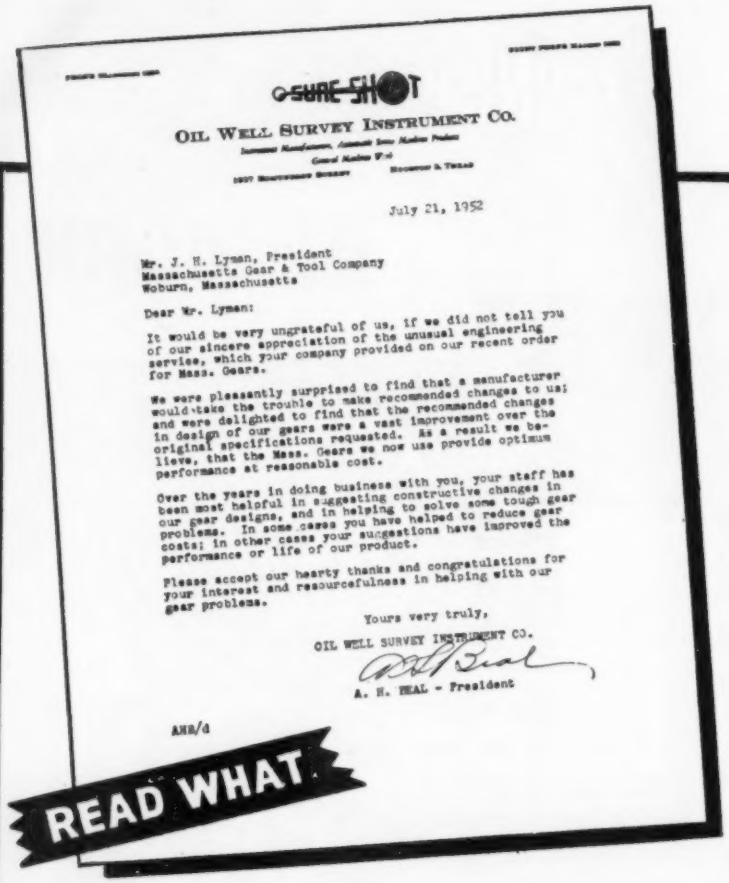

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Index of PRODUCTS ADVERTISED

In This Issue

•

(Continued from page 385)

MECHANICAL PARTS

Abrasives 294-295
Accumulators 366
Adhesives 80
Air Motors 310
Axles 301
Balls 320
Bearings, Ball, Roller, and Needle ....4th Cover, 16, 22-23 38, 48, 62, 96-97, 104, 120, 213, 241, 288, 291
Bearings, "Oil-less" 20-21, 31 239, 240, 340, 356
Bearings, Sleeve 20-21, 31, 109 240, 340, 351, 379
Bellows 26, 116
Belts 44-45, 294-295, 321 363, 390
Bolts, Nuts, Screws and Rivets 32, 40-41, 52, 61, 86, 219, 223 238, 254, 272, 279, 307, 338, 340 350, 372, 387, 392
Blowers 264
Bushings & Grommets.....109, 239 356
Carburetors 368
Chains 13, 76-77, 92, 348 376, 381
Clamps 225, 261, 358
Clips 314
Clutches 95, 284, 322, 328, 352
Containers 326, 390
Controls 242, 326, 380
Counters 17
Couplings, Flexible ..42-43, 81, 286 316, 376
Couplings, Hose & Tube..... 261
Drives 11, 24-25, 44-45, 301 352, 376
Engines 227, 270, 377
Fasteners—30, 32, 35, 40-41, 52, 61 73, 86, 118, 219, 223, 238, 254 272, 279, 290, 307, 318, 338, 340 350, 355, 361-362, 372, 387, 392
Filters.....326, 349, 358, 368
Flexible Joints 350
Floats 280
Gages & Instruments..72, 229, 231 352, 391
Gears...6, 27, 49, 268, 273, 280, 301 306, 317, 341, 367, 370, 374, 386
Hose 114, 294-295
Hydraulic & Pneumatic Equipment..1, 65, 93, 225, 250-251, 257 278, 281, 282, 285, 304, 310, 319 326, 336, 350, 353, 358, 364, 366 372, 380
Insulation 368
Joints 114
Lubricating Equipment...247, 275 278, 358
Mountings 42-43, 244
Name Plates..... 322
Packing, Gaskets, Seals.....20-21 31, 88-89, 101, 108, 216, 221 236, 247, 248, 287, 294-295, 311 331, 340, 352, 359
Photographic Equipment 263
Pins 318
Piping 67-70, 229
Power Units.....225, 227, 250-251 257, 278, 281, 304, 310, 350 364, 380
Pumps...56, 250-251, 257, 262, 265 278, 319, 332, 338, 347, 350, 353 356, 368, 380, 389
Rings.....20-21, 31, 73, 331, 352
Riveting Machines 304
Shafting, Flexible 354, 371
Shims 258
Speed Reducers & Motor Reducers..3rd Cover, 11, 49, 110-111 289, 308, 309, 341, 367
Spindles 211
Springs 346
Sprockets 280, 376

Index of

PRODUCTS ADVERTISED

In This Issue

•

Testing Equipment.....229, 352
Tapes 358
Timers 225
Tractors 301
Transmissions.....301, 308-309 352, 380
Traps 229, 280
Universal Joints.....272, 322, 329
Valves & Fittings....1, 65, 93, 229 250-251, 275, 280, 303, 304, 314 320, 336, 358, 365, 380
Vibration Dampers.....42-43, 244
Washers....109, 219, 239, 270, 352
Wire Cloth.....378, 390

ELECTRICAL PARTS

Assemblies 385
Brakes 293
Brushes.....20-21, 31, 340
Coils 267, 338
Connectors 105, 318
Contacts.....54, 64, 276, 334, 340
Controls & Control Equipment 12, 18-19, 24-25, 33-34, 37, 39 46-47, 54, 74, 235, 249, 252, 254 276, 283, 296-297, 299, 300, 303 316, 334, 342, 372, 391
Drives 27
Electronic Equipment...4, 330, 391
Extruded Plastics 233 320, 335, 336, 358, 365, 380
Heating Units..... 325
Instruments 391
Insulation 233
Insulators 380
Lamps 342
Motors.....3rd Cover, 24-25, 46-47 56, 78-79, 110-111, 246, 264, 283 289, 302, 350
Rectifiers 12
Solenoids.....39, 299, 303, 320 326, 334
Telephones 267
Thermostats.....66, 303, 316
Timers.....249, 314, 350
Transformers 267, 328
Wiring Accessories....328, 334, 346

DRAFTING ROOM EQUIPMENT AND SUPPLIES

28-29, 53, 263, 318

FABRICATING METHODS AND SERVICES

Assembling 306
Bending 85, 282
Drawing 85
Duplicating 282
Extruding 260
Finishing 85
Forming 85
Gear Cutting..... 6
Molding.....114, 255, 260, 324, 352 358, 369, 380
Pressing 304
Riveting 304
Shearing 282
Stamping.....85, 270, 282
Welding.....85, 253, 315, 325, 382

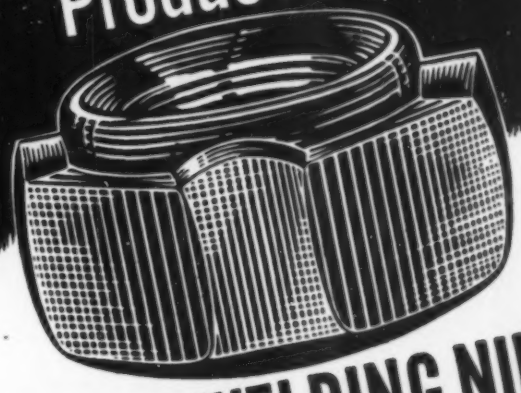
ENGINEERING AND PRODUCTION SERVICES

90, 269, 325, 377

BOOKS

58-59, 298

BIG in Efficient Production Plans



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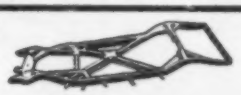

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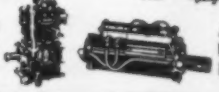

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INDEX TO ADVERTISERS

This index is published as a convenience to the readers. Every care is taken to make it accurate but PRODUCT ENGINEERING assumes no responsibility for errors or omissions.

Acme Chain Corp. 348
Alden Products Co. 340
Alemite 275
Allegheny Ludlum Steel Corp. . 339
Allen-Bradley Co. 33-34
Allied Products Corp. 269
Allied Research Products Corp. 330
Allis Chalmers Mfg. Co. . 24-25, 56
Allmetal Screw Products Co. Inc. 254
Alloy Precision Castings Co. . . 394
Aluminum Industries Inc. 323
American Brass Co. 343-344
American Chemical Paint Co. . . 256
American Hard Rubber Co. . . . 260
American Manganese Bronze Co. 380
American Screw Co. 32
American Smelting & Refining Co. 307
American Steel & Wire Div., U. S. Steel Co. 67-70
American Welding & Mfg. Co. . 325
Amgears Inc. 306
Anchor Coupling Co., Inc. 261
Armco Steel Corp. 206
Atlantic Screw Works. 32
Automotive Gear Works Inc. . . 273
Avco Mfg. Co. Lycoming-Spencer Div. 377
Avon Tube Div. Higbie Mfg. Co. 215

Barco Mfg. Co. 360
Barry Corp. 244
Bellows Co. 310
Beryllium Corp. 375
Bethlehem Steel Co. 10
Blake & Johnson Co. 32
Blood Brothers Machine Co. . . . 329
Bound Brook Oil-less Bearing Co. 239
Bower Roller Bearing Co. 16
Brainard Steel Co. 106
Bridgeport Brass Co. 91
Brown & Sharpe Mfg. Co. 347
Bruning Co., Inc. Charles. 53
Buffalo Bolt Co. Div. Buffalo-Eclipse Corp. 238
Bunting Brass & Bronze Co. . . . 351

Cambridge Wire Cloth Co. 390
Cannon Electric Co. 334
Carlyle Johnson Machine Co. . . . 95
Carpenter Steel Co. 320
Carpenter Steel Co., Alloy Tube Div. 14
Central Screw Co. 32
Centric Clutch Co. 322
Century Electric Co. 78-79
Century Hydraulics Inc. 372
Chace Co., W. M. 271
Chain Belt Co. 76-77
Chase Brass & Copper Co. Inc. . 335
Chemical Corp. 285
Chicago Rawhide Mfg. Co. 216
Chicago Thrift-Etching Corp. . 322
Chrysler Corp. Industrial Engine Div. 227
Cincinnati Gear Co. 374
Clare & Co., C. P. 235

INDEX TO ADVERTISERS

Clark Equipment Co..... 301
Cleveland Worm & Gear Co.... 49
Climax Molybdenum Co..... 364
Columbia—Geneva Steel Div.—U. S. Steel Co.....67-70
Connecticut Hard Rubber Co... 298
Continental Screw Co.....32, 223
Cornish Wire Co. Wired Assembly Div. 385
Coto-Coil Co. Inc..... 338
Cramer Co., Inc., R. W..... 249
Crane Company 229
Cuno Engineering Corp..... 349
Curtis Universal Joint Co..... 272

Denison Engineering Co....250-251
Dial Light Co. of America..... 342
Diamond Mfg. Co..... 374
Dings Brakes Inc..... 293
Dodge Mfg. Corp. 274
Dow Corning Corp..... 202
Drop Forging Association 332
Durakool, Inc. 254
Durez Plastics & Chemicals, Inc. 300
Durkee Atwood Co. 321

Eagle Lock Co..... 32
Eastern Air Devices Inc..... 264
Eastman Kodak Co., Industrial Photographic 263
Eaton Mfg. Co. Foundry..... 36
Elastic Stop Nut Corp. of Amer. 52
Elco Tool & Screw Corp..... 32
Electric Auto-Lite Co..... 204
Emerson Electric Mfg. Co..... 283
Euclid Electric & Mfg. Co..... 342
Evans' Sons, John 346

Fairfield Mfg. Co..... 268
Farrel-Birmingham Co., Inc... 341
Federal Bearings Co., Inc..... 97
Federal Mogul Corp. (Equipment) 109
Federal Telephone & Radio Corp. 12
Felters Co. 393
Fischer Special Mfg. Co..... 372
Fiske Bros. Refining Co., Lubriplate Div. 278
Flexonics Corp. 116
Foote Bros. Gear & Machine Corp. 27
Fulton Sylphon Div., Robertshaw-Fulton Controls Co... 26
Funk Aircraft Company..... 352

Galland-Henning Mfg. Co..... 314
Garlock Packing Co..... 311
Gast Mfg. Corp. 278
General Electric Co., Apparatus Dept. 37
General Electric Co., Monowatt Dept. 105
General Electric Co., Chemical Silicones Div. 57
Gerotor May Corp. 353
Giannini & Co. Inc., G. M..... 391
Gits Bros. Mfg. Co..... 247
Gleason Works 6
Goodrich Chemical Co. B. F. (Hycar) 8
Goodrich Co., B. F. (Rivnut)... 61
Goslin Electric Mfg. Co..... 328
Graphite Metallizing Corp..... 356

(Continued on page 390)

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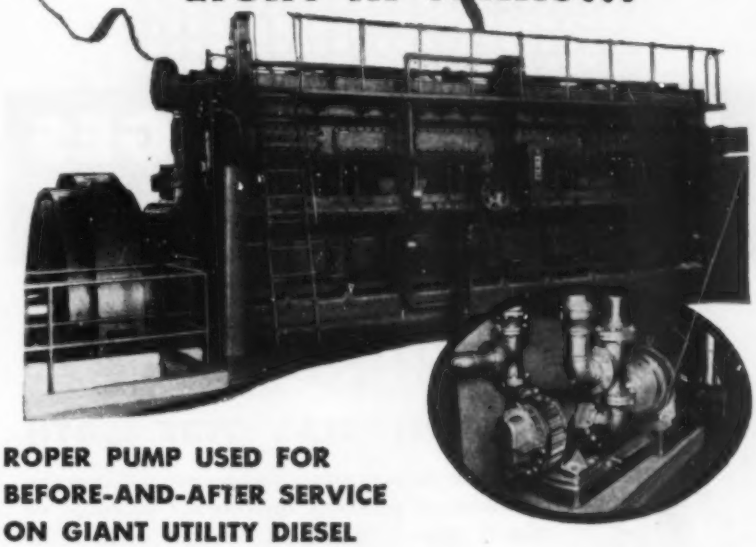

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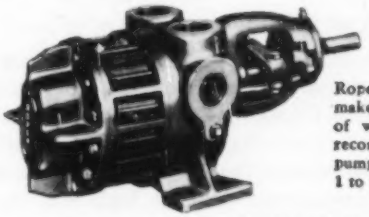

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371 Blackhawk Park Ave., Rockford, Ill.

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Rotary Pumps

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#1. Some manufacturers assign only one operator to as many as ten looms. But here at Cambridge, we have a specially trained operator for every single loom in the plant. Just a little difference . . . but a BIG advantage in accurate mesh count and constant screen width.

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#3. Some manufacturers are not equipped to fabricate wire cloth into special forms, for example, filter leaves. But here at Cambridge, we can supply wire cloth in bulk or in practically any type of fabricated part . . . a BIG advantage that saves you time and money by providing one source for both weaving and fabrication.

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Cambridge 1, Maryland

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INDEX TO ADVERTISERS

(Continued from page 389)

Graton & Knight Co. 108
Gray and Prior Machine Co. 322
Great Lakes Screw Corp. 32
Greer Hydraulics, Inc. 366
Gries Reproducer Corp. 350

Handy & Harman 259
Hannifin Corp. 304
Hansen Mfg. Co., Inc. 350
Harper Co., H. M. 32, 307
Haydon Co., A. W. 314
Haynes Stellite Co. a Div. Union Carbide & Carbon Corp. 357
Helm Co. 104
Heli-Coil Corp. 35
Heli Pot Corp. 72
Heyman Mfg. Co. 346
Hyatt Bearings Div., General Motors Corp. 62
Hydreco Div. N. Y. Airbrake Co. 336

Indiana Gear Works 317
International Nickel Co. Inc. ..60, 107
International Packings Corp. ... 108
Irvington Varnish & Insulator Co. 233

Johns-Manville Corp. (Packings) 359
Johnson Bronze Co. 379
Johnson Machine Co., Carlyle. 95

Kaiser Aluminum & Chemical Corp. 336-337
Kaydon Engineering Corp. 241
Keuffel & Esser Co. 28-29
Kold-Hold Mfg. Co. 245
Koppers Co. Inc., Plastics Div. 87
Koven & Bros. L. O. 90
Kraissl Co. 332

Lake Chemical Co. 316
Lamb Electric Co. 289
Laminated Shim Co., Inc., Shim Division 258
Lamson & Sessions Co. 32
Lapeer Mfg. Co. 358
LaSalle Steel Co. 305
Leach Relay Co. 372
Lebanon Steel Foundry 243
Lincoln Electric Co. 253
Linear Inc. 331
Link-Belt Co. 11, 13, 22-23, 92
Link Engineering Co. 231
Logansport Machine Co., Inc. ... 93
Lord Mfg. Co. 42-43
Lovejoy Flexible Coupling Co. . 316
Lubriplate Div. Fiske Bros. Refining Co. 278
Lycoming Spencer Div. Avco Mfg. Co. 377

McGill Mfg. Co. Inc. 291
McGraw-Hill Book Co., Inc. ... 298
M-B Products 358
Madison-Kipp Corp. 102
Mahon Co., R. C. 315
Malayan Tin Bureau 333
Mallory & Co., Inc., P. R. 4, 54
Manhattan Rubber Co. 294-295
Manheim Mfg. & Belting Co. ... 363

INDEX TO ADVERTISERS

Marsh Corp., Jas. P..... 352
Massachusetts Gear & Tool Co. 386
Master Electric Co. (Speed-master) .....3rd Cover
Mead Specialties Co..... 225
Metals & Controls Corp., General Plate Div..... 64
Metals & Controls Corp., Spencer Thermostat Div..... 66
Michigan Steel Casting Co..... 312
Micro Switch Div. Minneapolis-Honeywell Regulator Co..... 74
Midland Steel Products Co..... 387
Milford Rivet & Machine Co... 290
Miller Motor Co..... 285
Miniature Precision Bearings Inc. 48
Minneapolis-Honeywell Regulator Co. Industrial Div..... 303
Minnesota Mining & Mfg. Co... 80
Minnesota Rubber & Gasket Co. 101
Monarch Aluminum Mfg. Co... 306
Monsanto Chemical Co..... 71
Morse Chain Co..... 381
Mt. Vernon Die Casting Corp... 98
Mueller Brass Co..... 237

National Acme Co..... 39
National Lock Co..... 32
National Malleable & Steel Casting Co. 292
National Motor Bearing Co., Inc. 88-89
National Screw & Mfg. Co..... 32
National Tube Div. U. S. Steel Co. 67-70
Naugatuck Chemical Div. U. S. Rubber Co. 75
Newark Wire Cloth Co..... 378
New Departure Div. General Motors Corp. 120
New Hampshire Ball Bearings 288
Nicholson & Co., W. H..... 280

O. & S. Bearing Co..... 240
Ohio Gear Co. 367
Ohio Seamless Tube Co..... 100
O'Neil-Irwin Mfg. Co..... 282
Orange Roller Bearing Co., Inc. 213
Ortmann-Miller Machine Co... 282

Palnut Co. 340
Parker-Kalon Corp. 32, 86
Parker Rust Proof Co..... 84
Patton-MacGuyer Co. 328
Perkins Machine & Gear Co... 370
Pesco Products Co.—Borg Warner Corp. 257
Pheoll Mfg. Co.....32, 338
Pioneer Pump & Mfg. Co..... 262
Pittsburgh Plate Glass Fiber Glass Div. 94
Plastic Research Products Inc. 255
Polymer Corp. 388
Pope Machinery Corp..... 211
Precision Rubber Products Corp. 221
Product Engineering 112-113
Pure Carbon Co., Inc..... 340

R. B. M. Division of Essex Wire Corp. 276
Racine Hydraulics & Machinery Corp. 319
Ramsey Chain Co., Inc..... 376

(Continued on page 392)

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Low Torque • Many types and resistance values

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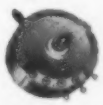

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Intermittent Rotary Power

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For high or low temperature

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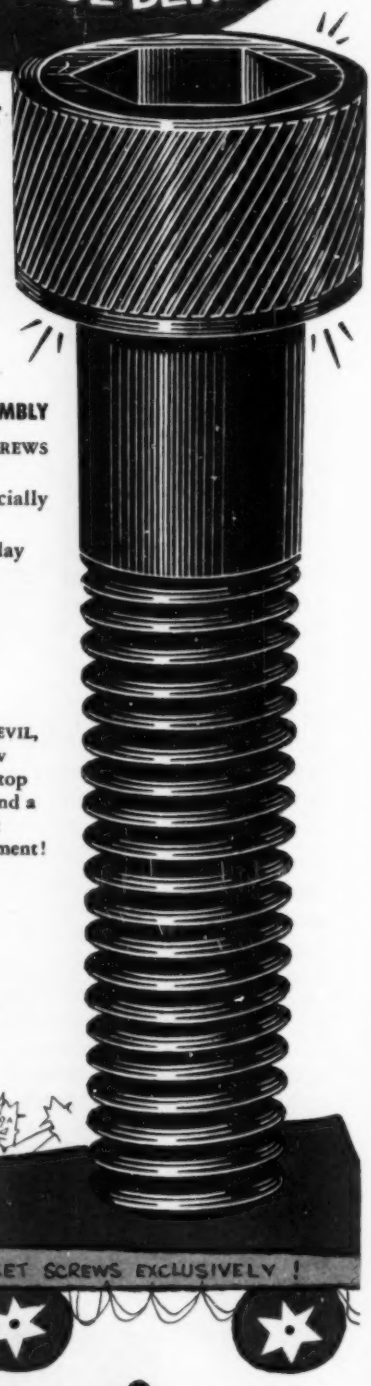

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INDEX TO ADVERTISERS

(Continued from page 391)

Raybestos-Manhattan, Inc. Equipment Sales Div. Manhattan Rubber Div. Packings Div. 294-295
Reeves Pulley Co. 308-309
Revere Copper & Brass, Inc. 2
Revere Corp. of America 242
Reynolds Metals Co. 361-362
Reynolds Metals Co. Parts Div. 85
Reynolds Wire Div. National Standard Company 83
Richardson Co. 114
Rigidized Metals Corp. 326
Robbins and Myers Inc. 265
Robertshaw-Fulton Controls Co. 316
Rochester Products Div., Gen. Motors Corp. 63
Rockford Clutch Div., Borg-Warner 328
Rockford Screw Products Co. 32
Rockwood Sprinkler Co. (Ball Valve Div.) 365
Roper Corp. Geo. D. 389
Ross Operating Valve Co. 1
Ruthman Machinery Co. 368

Safety Socket Screw Co. 392
Sauereisen Cements Company 368
Schatz Mfg. Co. 96
Schrader's Son, A. 65
Scintilla Magneto Div. Bendix Aviation Corp. Electrical Connectors 318
Scovill Mfg. Co. 32
Screw Research Association 32
Security Locknut Corp. 279
Servo-Speed, Inc. 300
Sessions Clock Co., Tyni-Switch Div. 252
Sewall Mfg. Co., E. B. 280
Shakeproof Inc. 32
Sharon Steel Corp. ..... 2nd Cover
Shenango Penn Mold Co. 266
Sherwin-Williams Co. 15
Simmons Fastener Corp. 30
Skinner Electric Valve Div., The Skinner Chuck Co. 320
Skinner Purifiers Div., Bendix Aviation Corp. 346
Smith Corp., A. O., Motor Div. 302
Soreng Mfg. Corp. 299
Southern Friction Materials Co. 322
Southington Hardware Mfg. Co. 32
Sponge Rubber Products Co. 369
Sprague Engrg. & Sales Corp. 350
Square D Company, Milwaukee 18-19
Standard Horse Nail Corp. 318
Standard Locknut & Lockwasher, Inc. 219
Standard Pressed Steel Co. 40-41
Star Kimble Electric Co. 246
Sterling Bolt Co. 32
Stewart Die Casting Div. Stewart-Warner Corp. 345
Stewart-Warner Corp. Alemite 275
Stow Mfg. Co. 371
Stronghold Screw Products, Inc., ... 32
Superdraulic Corporation 380
Superior Steel Corp. 103
Sweet's Catalog Service 58-59

Taylor-Winfield Corp. 382
Technology Instrument Corp. 330
Tennessee Coal & Iron Div. U. S. Steel Co. 67-70
Thiokol Corp. 287
Thomas Flexible Coupling Co. 286
Timken Roller Bearing Co. (Industrial) ..... 4th Cover
Timken Roller Bearing Co. (Steel & Tubes) 55
Tinnerman Products, Inc. 118

INDEX TO ADVERTISERS

Tomkins-Johnson Co. 364
Torrington Co. (Needle Bearings) 38
Trostel Packings Ltd. Albert. 248
Tuthill Pump Co. 356
Twin Disc. Clutch Co..... 284

Union Carbide & Carbon Corp. Hyanes Stellite Company.... 357
United Screw & Bolt Co..... 272
U. S. Gasket Co..... 236
U. S. Graphite Co.....20-21, 31
U. S. Rubber Co.....75, 82
U. S. Steel Export Co.....67-70
U. S. Steel Co. 67-70
U. S. Steel Supply Co.....67-70
Universal Clay Products Co... 380
Universal Drafting Machine Co. 318
Utica Drop Forge & Tool Corp. 327

Van Cleef Bros. Inc..... 358
Van Huffel Tube Corp..... 277
Veeder-Root Inc. 17
Vickers, Inc. 281
Viking Pump Co. 338
Vulcan Electric Co. 326

Wagner Electric Corp.....110-111
Waldes-Kohinoor, Inc. 73
Waldron Corp., John..... 81
Wales Beech Corp. 32
Ward Leonard Electric Co. 296-297
Waterman Engineering Co.... 326
Watertown Mfg. Co. 324
Weckesser Co. 314
Wellman Co., S. K..... 51
Wellman Bronze & Aluminum Co. 302
Western Felt Works 352
Westinghouse Electric Corp. 46-47, 50
Wheeler Insulated Wire Co... 267
White Dental Mfg. Co., S. S.. 354
Wisconsin Motor Corp. 270
Wolverine Tube Div., Calumet & Hecla, Inc. 99
Worthington Corp., Multi-V Drive Div. 44-45
Wrought Washer Mfg. Co.... 270
Wyman Gordon 373

Zenith Carburetor Div., Bendix Aviation Corp. 368

■

PROFESSIONAL SERVICES ... 384

SEARCHLIGHT SECTION
(Classified Advertising)
H. E. Hilty, Mgr.

EMPLOYMENT
Positions Vacant 383, 384
Selling Opportunities Offered ... 384
Positions Wanted 384
Employment Services 384

SPECIAL SERVICES
Contract Work 384

■

Advertisers' Index starts on 388

Product Index starts on... 385

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COULD BE **FELTERS FELT**

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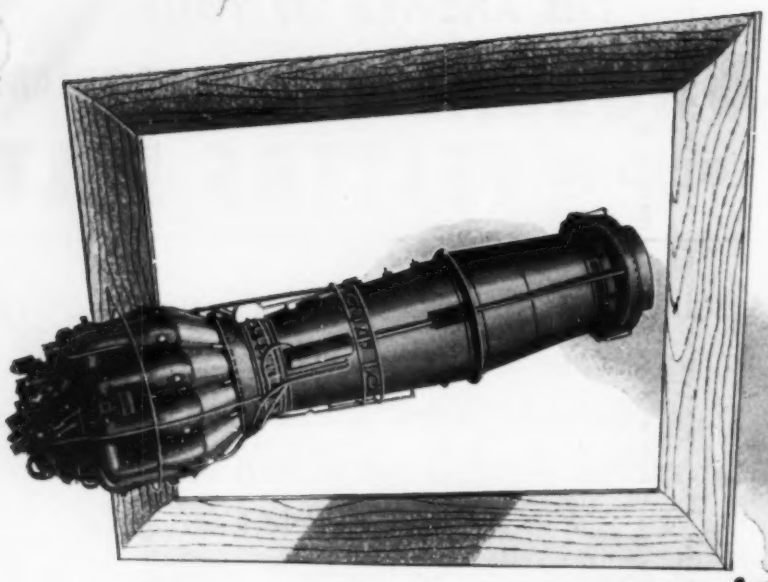

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cushioned power

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MASTER

FLUID DRIVE MOTORS

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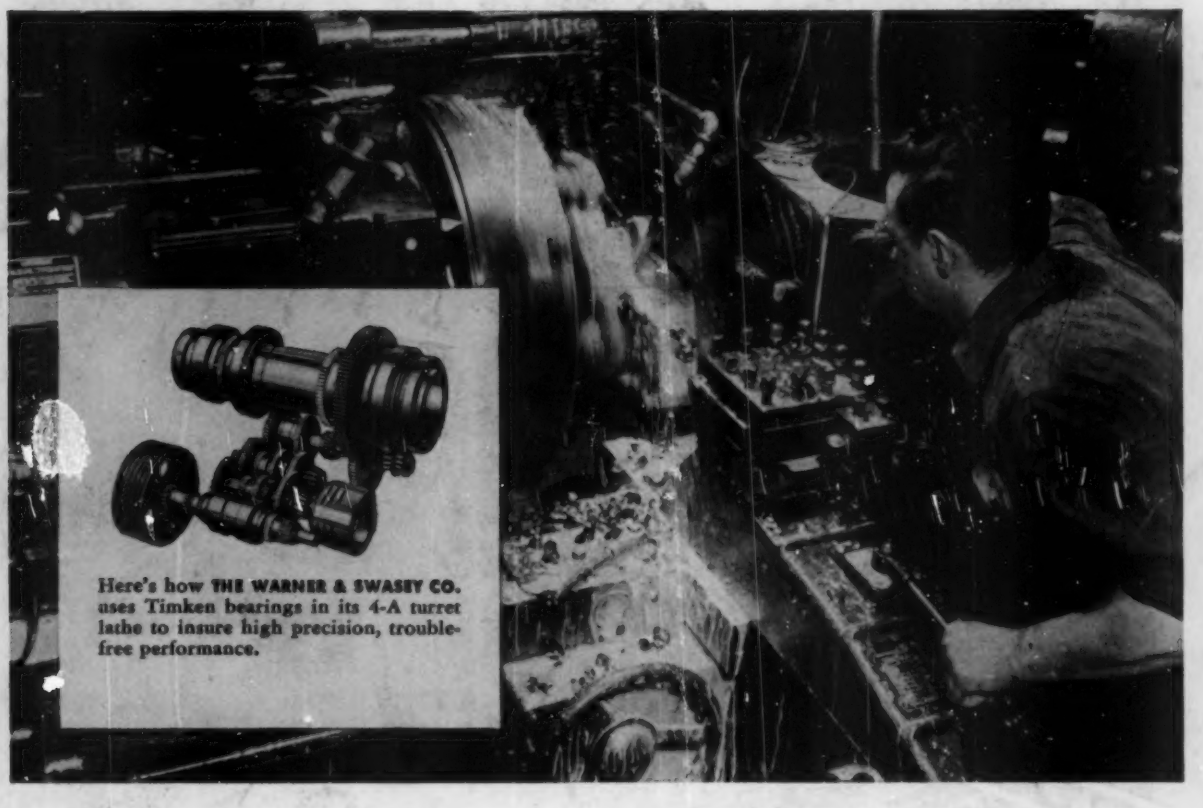
THIS Warner & Swasey 4-A turret lathe hogs off tough metal in a hurry, yet provides the high precision demanded for today's close-tolerance parts. Warner & Swasey engineers assure both precision and ruggedness by mounting the spindle and 12-speed gear train on Timken® tapered roller bearings.

Whether you're using a one-inch drill or making a 28" turning cut, Timken bearings maintain spindle precision and accurate gear mesh day in and day out. They are tapered in construction to take radial, thrust and combination loads. Line contact between rollers and races provides maximum capacity. Shafts are held in rigid alignment. Gear mesh is smoother, more accurate. Shaft wear is eliminated, gear wear reduced.

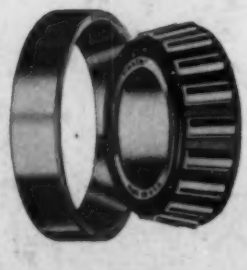
True rolling motion and an incredibly smooth surface finish combine to make Timken bearings practically friction-free. They're made from Timken fine alloy steel—finest steel ever developed for tapered roller bearings—and rollers and races are case-hardened for hard, wear-resistant surfaces and tough, shock-resistant cores.

No other bearing can offer you all the advantages of Timken bearings. Be sure to use them on the machine tools you build or buy. And look for the trade-mark "Timken" stamped on every bearing. The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

This symbol on a product means its bearings are the best.



Here's how THE WARNER & SWASEY CO. uses Timken bearings in its 4-A turret lathe to insure high precision, trouble-free performance.



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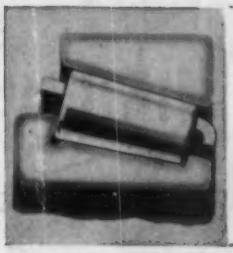
TAPERED ROLLER BEARINGS



GREATER LOAD AREA

Because the load is carried on the *line* of contact between rollers and races, Timken bearings carry greater loads, hold shafts in line, wear longer.

The Timken Roller Bearing Company is the acknowledged leader in: 1. advanced design; 2. precision manufacturing; 3. rigid quality control; 4. special analysis steels.

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